Packaging Closures and Sealing Systems

Edited by
Nigel Theobald and Belinda Winder

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Packaging Closures and Sealing Systems

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Nigel Theobald

1.1 General introduction

This book has been written both for the packaging technologist and for those people who wish to gain further knowledge of the basics of closures and sealing systems. Each chapter, written by a specialist within their field, is easily accessible even by those with limited knowledge of the specialist area being discussed. Great care has been taken to keep the technology simple for those who are less familiar with the jargon of the packaging industry, and also to ensure that the content of this book is 'state of the art' for the modern practitioner. Packaging has, in recent years, made the transition from an 'art' to a 'science', and it is also true that now, more than at any other time in the history of packaging, individual flair apropos brand management has become a necessity.

It is the blending of art and science that makes the packaging field so interesting and so necessary in today's market place. In the past packaging was not so important for the survival of the product than it is today. Designing the containers to specific shapes to attract the consumer is of little use if the sealing systems used are ineffective. Closure design and technology are in the forefront of the packaging technologists' tools for good commercial packaging. Without effective packaging, the whole concept of modern production, transportation and branding would not be possible. Today, the product does not exist without packaging – packaging is part of the product. Today, packaging is as important as the product and is the lifeblood of the modern consumer-driven society.

The art of packaging has been with us for most of the life of the human race. Hundreds of thousands of years ago, packaging consisted of the plants and animal products that were available in the immediate locale of our ancestors. As man became more sophisticated, gradual improvements in packaging took place either as short sharp bouts of development or as gradual changes over a period of time. Modern-day packaging is no different, in terms of its expectations, from that which was used centuries ago. The difference lies only in the ability of the human being to use the knowledge that has been acquired over the centuries and to better understand the processes of, for example, deterioration in products, and to combat these through specially designed packaging. Thus, growing knowledge of the ripening processes of fruit needs, or even demands, a careful choice of packaging materials, with the correct selection capable of either delaying the ripening of fruit and vegetables – allow for longer storage – or advancing the ripening – to allow for earlier crop gathering and ripening. The packaging technologist has an important part to play in the choice of these materials, as does the food technologist, who must decide on the parameters to be used for the selection process.

In former times, fruit and vegetables were available only in season; however, now it is possible, through the realms of technology, to obtain these commodities at any time throughout the year. Different products, previously thought to be available only in foreign countries, are now available in shops and supermarkets everywhere.

Modern-day products are far more sophisticated as the modern generation is more demanding, than was ever the case previously. Better protection of both the product and the environment are now paramount; new variants of older products – even those that are grown through agriculture – demand revision of the methods of protection that were previously considered more than adequate.

In addition, over the last decade, consumers have become increasingly concerned about the appearance of products; packaging that enhances the aesthetic appeal of the product inside (whether by simply framing the product in a visually pleasing way, or as a direct result of the technology that accompanies the packaging) has become crucial for healthy sales. For example, the packaging of red meat is designed both to give the product a longer shelf life than previously, and also specifically to enable the retention of a good ‘red’ colour (with the implicit message to the browsing shopper that this is a fresh and healthy product). Clearly, a consumer is less likely to purchase a pack of beef that is grey or brown in colour, as opposed to the one that is blood-red and positively (in the eyes of the consumer) exudes freshness. Both packs of beef may have been stored under identical conditions, and be of the same ‘age’, but the choice of packaging material/closure, and its effect on the product inside, will frequently dictate the consumer’s preference.

It should be noted, however, that the world of the packaging technologist is not quite the playground of possibilities it seems to be. Over the past few years, there has been a transformation (which is ongoing) in the way we view our responsibilities towards each other, towards the animals and plants around us and towards the environment we live in. These transformations in the attitude of consumers towards a more socially responsible and (in general) healthier way of living are indeed determining the direction and focus of packaging and retail industries. In addition, as a response to both these changing social attitudes, in the light of emerging medical knowledge about people’s diets and health, and increasing environmental awareness, the packaging industry finds itself ‘pulled’ along by the requirements of government legislation.

Moreover, the continuous revision and interchange of products, the advent of novel packaging technologies and manufacturing techniques, and the need to conform to current and incoming legislation will result in a need to review products’ packaging on a regular basis. However, without a thorough grounding in the entire range of packaging technologies (and not just the main area of specialism), the packaging technologists will not be able to ensure that they have designed the optimal pack for any given product. Crucial to creating this optimal pack is the choice of packaging material and the sealing method used. The packaging technologist must, by necessity, be aware of all the advantages and shortcomings of potential packaging materials. Furthermore, since it is the pack closure that acts as the primary conduit between the consumer (or user) and the product itself, the importance of the closure cannot be emphasised enough.

1.2 Market size

An indication of the importance of closures is clearly reflected in commercial terms by the size of the market. At the turn of the century, the market value of closures on a global scale was approximately $15 billion. In Western Europe, this figure was around $5.4 billion, over one-third of the total. With the increase in market size by about 4% per annum, this gave a global value of about $18.5 billion in 2005.

The breakdown of materials according to the value for 2005, however, stays approximately the same as that shown for 2000 (Fig. 1.1). This shows that the relative value of materials remain the same, although the number of items contributing towards the packaging may change. The latter is unpredictable, since many other factors affect the change (legislation, material availability, etc.).

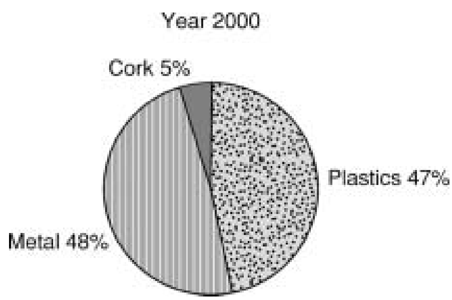

Figure 1.1 Types of closures by material.

The market segmentation on the basis of the use of different materials shows that by far the most important use of closures is in beverage market. Introduction of new materials and designs will no doubt influence the market in the future years.

In 2005, there was an increase in the food and pharmaceutical areas and, thus, a corresponding decrease within the beverage area (Fig. 1.2). However, this pie chart

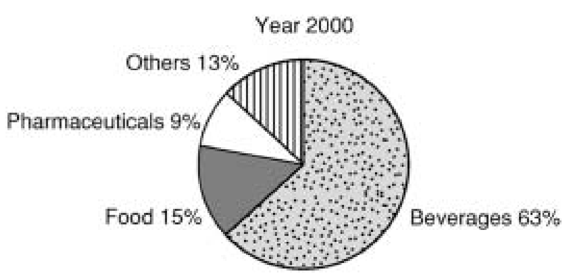

Figure 1.2 Western Europe closure sales.

shows sales for the total of the market, and it should be remembered that the total market is still growing. It can be seen from the above pie chart that the beverage closure market is the strongest in Western Europe, with 63% of the sales. This is also the strongest market for cork, which has a 5% share of the market. However, in several countries the latter is being affected by the use of 'plastic cork' for wines.

In addition, there is a rising trend for sports drinks (for beverages) used for energy-building post-sporting activity. Bottled water also has a strong influence on sales; there was a significant rise in sales of bottled water in the recent years. It is unclear how much of this growth is due to the introduction of easy-to-open closures that are convenient to drink from – or whether the trend is more directly linked to the changing societal needs.

Milk packaging has also changed with a greater use of 'plastic bottles' and composite cartons replacing the more traditional glass bottle – with the latter, closures have changed from the aluminium foil cap to either plastic caps or dispenser units in the cartons – and the sight of a leaking milk bottle is a rare one indeed.

The food and drinks market in Europe was valued at about 572 billion Euros in 1999 and there were some 26 000 companies in the sector. It is unlikely that this will diminish as the years progress, since all of the countries are seeing a steady rise in the population (except for Poland and Czech Republic). Within the European Union (EU) there is a steady rise in gross domestic product (GDP) (approximately 2% per annum) and in earnings (about 3.5% per annum). Both of these are strong indicators of the growth of the food and beverage markets. However, if we look at the producer price indicators, these show a much higher rise (5.2%) over the last few years than the rises in the GDP and earnings. Industrial output has also shown a trend for marginal growth in many EU countries, with the exception of Eire, where the industrial growth has maintained a good level of progress (industrial output index of 163.9 for 2000, based on 100 in 1995). The improvement in the market size depends on many factors and varies from country to country. However, it is unlikely that the overall market throughout the world will decrease with time. However, care must be exercised to ensure that cost-effective solutions are found when new or redesigned packaging is being considered. Packaging is an essential part of the product-selling concept, and without effective packaging the consumer will not return for a repeat purchase.

There is no doubt that the closure market is the largest of all the markets within the packaging industry. Nearly all of the containers produced require a closure of some type or other and, in addition, all the flexible packs produced can be considered as both the container and the closure system. It is difficult to estimate the actual size of the market because of its diverse nature and lack of distinct figures available for different areas or specifically for closures. Thus, the value of the individual markets can be estimated only by reference to the main area markets for the different types of packaging items. However, the market size is considerable and small deviations from actual to estimates may not have a significant influence on the overall value.

The estimate of the total quantity of containers (excluding flexible packs) produced in Western Europe is around 170 billion. Of these around 50% (85 billion) are metal closures and some 4.6 billion are aerosols. Europe is the world's largest producer of aerosol containers with about 40% of the world's production (i.e. 10 billion). However, closures are not the only areas of consideration here.

The data in Table 1.1 set the scene for the importance of the closure industry in the world market. The need for designers and technologists to think carefully about the methods of closure design and construction has never been more vital than it is today – with an emphasis on the need to conserve resources, produce economically and protect the product, as well as provide the customer with the best means of dispensing the product.

Table 1.1 Some usage of closures and containers

Industry	Location	Annual usage
Drinks	EU	
Carbonated		28 million
Other Soft		10.5 million
Water		36 milliom
Fruit Juice		9 million
Medical Devices		
	EU	3.9 billion
	USA	6 billion
	Japan	2.5 billion
	ROW*	3.6 billion
Cosmetics		
	Germany	1.1 billion
	France	0.9 billion
	UK	0.8 billion
	Italy	0.8 billion
	Spain	0.5 billion
	EU15	3.1 billion
	USA	3.2 billion
	Japan	1.6 billion

* rest of world

The ever-changing legislative requirements also place a burden on designers, technologists and marketers to the extent that a plethora of considerations will impact on the choice of the closure type. With an abundance of variety available, both in materials and types of closures, the decision making is becoming increasingly complex; nevertheless, a good decision is imperative if the brand is to be successful.

1.3 Choice of material for containers and closures

The success (or failure) of a product can invariably be traced to the tripartite combination of product, container and closure; indeed, it may be the combination of these three elements that may help dictate the sales trajectory of a product. Moreover, as emphasised in the opening lines of this book, the closure is the conduit through which the consumer will experience a product. Choice of potential closures will be significantly affected by the choice of container. The following section will whet the reader's appetite concerning the diverse types of materials that may be used for both containers and closures. A far more comprehensive description and evaluation of these materials as container types, and their capacities or potential with regard to possible closures, are presented in Chapters 3 (metal containers), 4 (glass containers), 5 (paper/composite containers) and 6 (plastic bottles and tubs), whilst Chapters 7 and 8 focus on push-on and flexible closures and sealing systems, respectively.

1.3.1 Metals

In packaging industry, the commonest types of metals used both for containers and for closures are tinplate and aluminium. Tinplate is a tin coating on the surface of a steel base, where the tin coating is varied in thickness to achieve the desired level of protection for the contents and the steel structure. The tin coatings may be, and often are, again coated with a lacquer to protect the product from the tin. A wide range of closure types are used on metal containers, some of the different types of closures that are used for metal containers are shown in Fig. 1.3.

Figure 1.3 An assortment of metal containers displaying a variety of closures.

1.3.1.1 Tin

Tinplate is basically a steel structure with a thin layer of tin deposited on either one side or both sides, in order to give the steel some protection from corrosion when it is in contact with the product or the environment. The rigidity of the tinplate makes it an ideal material for many applications, whilst its rigidity is an advantage in some applications, the very rigid nature of tinplate does prove disadvantageous in others. Moreover, there is a possibility of a reaction between tinplate (when used as a closure) and, for example, an aluminium container. Electrochemical reactions may take place, leading to corrosion within the sealing areas. Most tinplate closures are, of necessity, coated with special lacquers to avoid any reactions with the products that are contained within the container; different lacquers are used according to the product type.

1.3.1.2 Aluminium

Aluminium has an advantage over tinplate in that it is lighter in weight and can be easier to shape. Closures using aluminium require different 'temper' (ductility) of material to successfully complete the closure system, but aluminium can be formed into both thick (rigid) and thin (flexible) closures. The thick rigid closures are used mainly for cans or aerosol containers, whilst the thin flexible material is used primarily for the closure of pots, bottles or thermoforms. In its flexible format, it can be formed to different tempers, such that the properties vary to give the desired attributes for the closure performance. Milk bottle closures traditionally use a soft temper (so that they can be pushed off without tearing), whilst blister packs use a hard temper (so that the tablet can be pushed through the material). It should be noted that the thinner the material, the greater the possibility of minute holes; thus, it cannot be asserted (with very thin materials) that the permeability is zero on all occasions.

1.3.2 Glass

Glass is mainly considered as a container material, but there are several uses of glass as a closure material. Glass containers use a variety of different closure systems, some of which are illustrated in Fig. 1.4.

In the past, glass stoppers were more common, with some stoppers even containing 'marbles', which helped to hold pressurised gas inside a carbonated drinks container. Nowadays, the main use for glass stoppers is in laboratory ware; the stoppers for many reagent bottles are glass, where the shape of the stopper and the container are positioned to give a good fit to each other. However, this is not the only use for glass stoppers; they are also used for the expensive cosmetic and perfume markets, to give that all important feel of luxury.

1.3.3 Paper materials

1.3.3.1 Paper

This can be used as a flexible wrap for products, or as a closure material for pots and jars. Most paper materials are used with a liner applied either as a laminate or

Figure 1.4 An assortment of glass containers displaying various types of closures.

as a coating. Paper, by itself, is very porous to moisture and gases, hence the use of the laminate or coating. In such cases, paper is indeed suitable to provide a carrier material for the barrier, providing the bulk for the much thinner (or fragile) barrier layer. However, its importance within the closure industry should not be overlooked or underestimated.

1.3.3.2 Cartonboard

Cartonboard is a product of the paper industry, and it is used extensively in the closure industry. It may be used either as a carton, where the pack and closure are integral and the seal is a part of the complete structure, or as a liner for cap closures. In the latter instance, the property of cartonboard to deform under pressure is exploited to allow for the seal between the container and the closure to be affected, even where there is some irregularity between the 'matching' components. In most liner applications, the cartonboard will be lined or coated with another material to give the desired properties.

1.3.3.3 Corrugated board

Although most people would not consider this as a material for closures, it is widely used for heavier packs in both retail and industrial packaging. As with cartonboard, the container and the closure are typically conjoined. Different grades of corrugated board may be used, depending upon the final requirements for the pack; the grades will vary from single-facing corrugated board for wrapping around semi-flexible applications, such as postal packs, through to multi-walled corrugated board for heavy industrial packs, such as car engines.

1.3.4 Plastics

The term *plastic* covers a vast range of materials that are, to all intents and purposes, compatible with most other forms of packaging material. Many different forms of closures are available in plastic materials, from the simple mono-layer materials used to over-wrap other packs, to the highly complex multi-layer materials that form specialised closures and containers. Plastic materials vary in use, depending upon the properties that are demanded from the specific packaging requirement. Plastic containers may utilise either plastic or non-plastic closures; in fact, the possible combinations are almost endless, as exemplified in Fig. 1.5.

Figure 1.5 An assortment of plastic containers displaying a variety of closure types.

1.3.4.1 Polyethylene

The basic material of polyethylene (PE) can be classified into several different forms and grades, ranging from the linear-low-density (LLDPE), through to low-density (LDPE), medium-density (MDPE) and high-density (HDPE) polyethylene, each having its own specific attributes and manufacturing qualities. Each of these polyethylene materials has a specific role to play in the design of the packaging and closure systems, for the closure cannot be considered in isolation from the container, and these should always be visualised as two complementary items that give the complete pack the specific attributes.

LDPE is usually used for closures in the food and beverage markets, where snap-on closures are required, since the flexibility of the material gives a good snap and reuse facility. Where tougher materials are required, the preference is for HDPE materials. HDPE materials also have better organoleptic properties and are often chosen for sensitive products.

Consideration of these types of materials would involve the designer thinking about the stability and compatibility of the intended products with the packaging materials. Moulded components do have, within their structure, built-in stresses, and these are liable to be relieved in failure, if the conditions are such that the polymer cannot maintain a cohesive structure. This is commonly referred to as *environment stress cracking* and can lead to the cap on a container cracking, thereby allowing product leakage.

1.3.4.2 Polyethylene terephthalate

This is a material that is more commonly used for the container, rather than the closure. However, there are some instances in which it is used in closure systems; in such cases, it is typically used either as a lidding material or as a twist-wrap material for confectionery. Polyethylene terephthalate (PET) may also be coated or co-extruded with other materials to give differing properties to the final film.

1.3.4.3 Polypropylene

This is a common material used for closure applications, because it possesses most of the good properties of the PE range within a single material. Polypropylene (PP) makes very good hinge lids, with a good repeat performance over many closure applications; it is widely used in food, beverage, cosmetic and pharmaceutical products. There are two basic types of materials: homopolymers – which have high rigidity and low impact strength; and copolymers – which are more flexible and perform better at low temperatures.

Due to the high rigidity of PP, due care must be given to the seal integrity when PP is used in the closure and other polymers are used in the container; in these circumstances, the use of a liner material in the cap should be considered.

1.3.4.4 Polystyrene

Similar to most other plastics materials, polystyrene (PS) is also available in more than one type. General-purpose polystyrene (GP) can be formed with high clarity, and thus it can be used for ‘glass clear’ applications. However, in this form it is very brittle and liable to shatter if it is subjected to rough treatment.

Another type of polystyrene is *high impact polystyrene* (HIPS), which also has a good gloss and clarity, although it does exhibit a white marking when stressed (rather than the shattering as in the GP material). PS has been used for lidding materials for vacuum-formed trays, where the low oxygen barrier properties can be exploited to retain the red colour for meats. However, because of its brittle nature, it is liable to tearing on closing machines. With the many other materials available, the use of PS is declining in the closure industry.

1.3.4.5 Other plastics materials

Many other materials are available within the palette of the closure designer to give the material the specific properties. For example, there is *acrylonitrile butadiene styrene* (ABS), which has the ability to withstand elevated temperatures without distortion; this is used for steam-sterilisable products.

In addition, one may consider nylon – this comprises a family of products that may be chosen on account of their particular attributes; for example, they are often used for cosmetics closures, since they have good scratch resistance; they may also be used for further finishing operations, such as electroplating. Another such material is *ethylene vinyl acetate* (EVA), which is mainly used as a lining material when the sealing function of the closure is paramount.

Although it is vital to consider the material used for the closure (and container), it is also important to consider the other factors that go into producing a successful pack/product within the market place.

These factors are the general functions that the pack needs to perform to be both legal and successful.

1.4 General functions of packaging

If it were possible to efficiently preserve products, and to distribute and market them safely and effectively through the production process and the distribution chain, without packaging, then packaging would not be used. Nowadays, the purpose (and functions) of packaging is manifold:

(1) *To protect the product from the environment.* Many of the products that we pack and market today have a limited shelf life, due to interaction with their environment. This may occur during the manufacturing process, while using the product to manufacture another product (an intermediate product), the shipping process, storage, marketing or use (misuse?) by the consumer. Products may need to be protected from many hazards that occur in any or all of these environments.

Other environmental considerations are the presence of dust, microbes, yeasts and bacteria in the atmosphere. All of these can have detrimental effects on the products, and packaging is designed to protect the product from their harmful effects.

(2) *To protect the environment from the product.* Many products may be harmful to the environment, or may have an adverse reaction with the environment; as

a result, the product may be degraded or changed, thereby limiting its use to the consumer. It may also be true that changes in a product, due to interaction with the environment, may render the product harmful to the consumer.

(3) *To maintain the product in the state in which it was produced until the end user can use it.* Many products are manufactured to a degree of consistency that is necessary for their effective use. For example, creams created for skin application on tender skin would be unacceptable if they were allowed to go hard and thus have an abrasive action on application. The manufacturer makes all products with a view to their final use, and any deterioration could render the product unacceptable.

(4) *To form a suitable sales unit.* Many products are permissible only if they are sold in fixed quantities. Others are sold in known quantities, and still more are packaged to be sold as a convenient unit – the latter may comprise a number of individual product portions, which have been designed so that the consumer can buy and transport 'in bulk', and which can be easily separated at home for use (see Figs. 1.6 and 1.7).

Figure 1.6

Figure 1.7

Before packaging was used extensively for products, each store would buy in bulk (packaged) and sell to consumers in smaller quantities, wrapping in paper or the like. Thus, the shelf life of the product could not be predicted and many products were damaged, either in store by break bulk, or in home due to poor storage.

(5) *To safely transport the product through the distribution chain.* Transportation through a modern transport and storage system, either within a country or via a worldwide distribution network, demands modern packaging. The journey hazards are numerous with palletised storage; movement by fork trucks or conveyor belts; road, sea or air transport (or a combination of all of these); reduced pressure (air transport or destinations at increased height above sea level) and variations in temperature and/or humidity. All potential hazards need to be thought through if the product is going to arrive safely at its final destination – the consumer.

(6) *To identify the brand.* It has only been in the last 200 years that brand identification has begun to play an important part in the marketing of goods. Prior

to that products were sold unwrapped and with variable quality. Now the majority of products and companies have a brand identity; indeed, the valuation of companies may differ significantly according to a commercial rating of their brand image. Brand loyalty amongst consumers is highly valued by the brand owners; since advertising is expensive (and in many instances of unknown value), a strong brand loyalty can minimise the need for advertising. The use of brand names to create a family of products can also have an advantage for the sale of other products (see Fig. 1.8 for an example of the use of a well-known brand to attract loyal customers to a new product).

Figure 1.8

(7) *To sell the product to the consumer.* The pack here serves two vital purposes: to sell the product to the consumer, and to allow the consumer to recognise the product for a repeat purchase. In the modern, consumer-orientated society, and the rush in shopping in the super (hyper) market, the consumer spends approximately one-tenth of a second scanning a shelf; this is all the

time your product has to make its presence known. The product shown in Fig. 1.9 is a good example of packaging that can more than hold its own on the supermarket shelf.

Figure 1.9

(8) *To inform the consumer of use.* A further function of packs is to inform the consumers of the appropriate ways to use the product – and to warn them of the dangers that may exist in use. Packs also provide other information, such as ingredients lists, storage conditions, shelf life, the name of the manufacturer and a host of other data. Much of the information may be a legal pre-requisite, with restrictions on minimal type size and legibility, depending upon the product.

(9) *To warn the consumer of dangers.* Some products, if used incorrectly, are dangerous; thus, the pack can also be used to give warnings (see Fig. 1.10).

Figure 1.10

Again, these warnings may be a legal requirement, or they may be placed on the pack by a concerned manufacturer (concerned for the consumer, their own public relations, or indeed loss of their own profit from successful consumer litigation).

(10) *To attain and maintain a cost-effective unit.* Packaging needs to be cost-effective, considering all the parameters that it is required to fulfil; it must be usable and safe for the consumer, and also efficient to produce and safe to transport. Differing legal requirements, languages, cultures and tastes throughout the world may mean that a compromise has to be made between a cost-effective product that is sold in an identical pack everywhere, and a more expensive product that is individually tailored to each country's consumers.

(11) *To protect the consumer.* With modern-day problems of tampering in store and out of store, the packaging may need to have the additional requirements of 'tamper evidence'. In general, it is accepted that ideally, tamper-evident features must be seen by the consumer at the time of purchase (see Fig. 1.11).

Figure 1.11

Tamper evidence is of no use if the consumer is unaware of the feature and how it works. Thus, any tamper-evident feature (there is no such thing as tamper proof!) must be easily seen and easily used. Additional protection for the consumer may be required by law for certain products, such as those that could be dangerous if used incorrectly (for example, bleach or other products that may require a child-resistant cap, or warnings for blind consumers). More comprehensive coverage of tamper evidence and child resistance may be found in Chapter 9; in addition, some relevant sections relating to the psychology of openability, together with data on poisoning accidents and injuries, can be found in Chapter 2 of this book.

All the functions listed above provide the manufacturers with a rationale for choosing one form of packaging over an alternative. All are important, although depending on the product and the market, some functions may take precedence over others; however, this should be as a result of measured contemplation, and not of injudicious omission.

Each component of the package should be considered, both individually and in a holistic sense, in order to ensure that the total package is the best possible one for the product. It may be that by using the best possible protection for the product, the cost of production becomes too high (and thus the product will not sell). This is not the best result for the product. Reducing the level of protection (reducing the shelf life), and thus reducing the cost of production, may make the product saleable and achieve a better result for the product, over the extended shelf life afforded by a superior pack.

Hence, a number of different tensions must be reconciled to achieve success. Although the packaging must fulfil the functions noted above as a matter of course in the eyes of most people (anything less would be viewed as sub-standard), more must be done to capture the eye, heart, money and loyalty of that valuable prize – the average consumer.

One of the most important parts of the pack is the closure system. This not only has a major effect on the shelf life achievable but also determines a major part of the customer satisfaction for the product. A poor closure system can lead to poor shelf life and also to the customer being taken to hospital either for food poisoning or for cuts and worse to their bodies. How much of this was the responsibility of the package designer not considering sufficiently the openability of the pack? As a thought, I liked the warning that appeared on a pack of a food product – 'If all else fails, kindly read instructions'.

1.5 Closures

A single-sentence definition of a good packaging closure is impossible, since the requirements of the closure system are manifold. A good closure should marry well with the container that it is closing, and the two should work in harmony with each other to maximise consumer enjoyment of the product. A good closure cannot compensate for a poor container or a poor product; however, a good closure *can* make a good product a must-have item, and can assure long-term re-purchasing by consumers. Thus, the choice of closure is critical in the design and selling of a product, and the added value of an innovative closure that has been carefully designed and crafted with a specific purpose in mind is exemplified by the 'Glottle' closure produced by the UK company, Rockware Glass (see Figs. 1.12 and 1.13, which are reproduced courtesy of Rockware Glass).

Unfortunately for the packaging technologist, the choice of closure for most products is not straightforward, as is evidenced in the following sections.

1.5.1 Role of the closure

Of course, almost every pack needs a closure and, while the addition of the closure may be one of the last operations carried out on the packing line, the closure itself forms a large factor in deciding whether a consumer will purchase a product again.

Figure 1.12

Research has shown that if the consumers have difficulty in opening a pack, they will look elsewhere. The consumer will often think of our closure being their opening! In this respect, designers should think how their pack will be opened and, if applicable, the role of the pack closure in that function. Another point to remember is that a pack is only as good as its closure. Thus, if the closure does not seal correctly, what use is a glass container that is impervious to the transmission of gases? These two points should be borne in mind when reading the rest of this book.

To be effective, a closure must conform to some general principles. Of course, there are variations in the principles that need to be considered for different materials and container types, and these will be outlined in the relevant chapters of this book. However, notwithstanding the idiosyncratic variations noted above, as a rule, an effective closure must

(1) *Seal the container.* Although this is an obvious rule, it may well be the one that is inadvertently overlooked in the objective of the pack. The materials used for the container and the closure may interact in unexpected ways when subjected to differential temperature or humidity conditions. Thus, the first

Figure 1.13

general rule is that the closure must be capable of sealing the pack under all normal conditions of use and storage (Note: the term 'normal conditions' should reflect how consumers treat the pack, rather than the expectations of the packaging technologist).

(2) *Be easily applied for packing line efficiency.* Packing line efficiency may be a greater consideration and may have a more significant effect on the total cost of the product, than the actual cost of the closure used. Disruptions to packing lines by poor application, or the mis-feed of components, will increase costs dramatically.

(3) *Be easily used by the consumer.* The consumer must be able to use the pack and closure system effectively. The closure may well be the best available for the product and the packing line, but if the consumers find difficulty in use, then it is highly likely that they will not purchase another pack of that type. Great care should be given to the testing of the closure by 'normal' consumers. Remember that the normal consumers for the product may have different capabilities (reduced sight, motor deficiencies in limbs, memory loss, etc.) or may include children – this is particularly important in terms of child-resistance closures that give this feature.

Some products rely heavily on their packaging closure to facilitate their usage (see Fig 1.14), and this is always appreciated by consumers – if it works; however, if the closures designed to aid the use of the product do not work – possibly because poor-quality materials are used, the finish is deleteriously affected by a lack of quality control in the manufacturing process or even because the initial product and closure design has not been properly tested on ‘real’ consumers (but just on ‘yea-saying’ focus groups) – this will irritate, even enrage, consumers and may have a very negative impact on the brand and/or the parent company’s image.

Figure 1.14

(4) *Be resistant to tampering within the supply chain.* In this day and age, it is an unfortunate fact of life that the contents of a pack often require protection from human beings in the form of tamper evidence. A working definition of this term is provided by the FDA (Food and Drugs Administration) in the United States as ‘having an indicator or barrier to entry which, if breached or missing, can reasonably be expected to provide visible evidence to consumers that tampering has occurred’.

It should also be remembered that no pack is tamper proof. Given sufficient time, resources and intent, it is hard to think of a pack that cannot be breached. Packs can differ in the degree of resistance they offer against tampering, however, and many suppliers have developed ingenious solutions to the problem of tampering. In many cases, it is the closure that can provide a level of tamper evidence/resistance; thus, this is another reason for selecting a closure with care.

The best that a technologist can hope for is that the consumer will be vigilant and will spot a tampered pack before use. Many tamperers want publicity and, thus, having tampered with goods, they will then proceed to inform the press of their actions. Tampering incidents cost manufacturers a great deal of money by way of stock recalls and additional checks on the product; thus, it is preferable for tamper evidence to be evident before the consumer uses the product, and ideally at the time of purchase. One company's attempt to do just this (by placing a *removable* warning on the packaging) exemplified the lack of foresight that can sometimes be seen in the packaging industry – where a design change is rushed into being with insufficient consideration of typical human behaviours.

(5) *Not cause harm to the product* (*or allow reactions from environmental components or allow egress of elements of the product into the environment*). Robust checks will need to be carried out in order to ensure that no component of the pack reacts with the product to cause degradation or harmful additives. Packaging technologists should remember that a reaction is most likely to occur once the pack has been used for the first time and the product has come into contact with an element in the closure system with which it was not in contact prior to use.

(6) *Be cost-effective for the application requirements.* It is relatively easy for a technologist to choose a closure system that will fulfil all the criteria that are requested *and* be the best closure on the market. For example, a custom-moulded closure that meets all the relevant criteria, but is slow to mould, has high assembly costs and additionally has slow application rates on the packing line may be the best closure for the product. However, it is likely to be the one that puts the final packed cost of the product well out of reach of the sales price at which the consumer is likely to purchase. Thus, it is *not* the best solution for the product.

1.5.2 General considerations in choosing a closure

Types of closure may range from metal, through to plastics, glass, cork, rubber or other natural materials. Regardless of the composition of the eventual selection, the actual process for choosing will proceed along a very similar path. Certainly, thought must be given initially while choosing a material that is compatible both with the product itself and with other components within the package. The typical expectations of the specific product market will need to be taken into account, together with any relevant legislative requirements for the local, national and/or international markets that are likely to be solicited. The assessment of an intended supplier's capability and capacity to produce the closure should also be considered. A more extensive, but not exhaustive, list of relevant factors is detailed in Table 1.2.

Table 1.2 Which closure?

1.	Is the product to be sold locally, nationally or exported internationally?
2.	What is the chosen supplier capable of achieving?
3.	Are the materials that have been chosen available (and are likely to continue to be available)?
4.	What legislation needs to be considered (local, national or *multi-country*)?
5.	Is any investment required by the packer, supplier or brand?
6.	What is the cost of the materials?
7.	Have potential environmental impacts been considered?
8.	Will the closure run efficiently on existing filling lines?
9.	What are the volume requirements, both initial and forecasted?
10.	Is the closure a brand line extension (to fit in with other packs on the market) or a new line?
11.	How is the closure (and the pack) to be decorated?
12.	What barrier requirements are necessary?
13.	What considerations need to be taken for any 'downstream' operations, such as assembly, *filling, packing, handling*?
14.	Is the closure (and all its components) compatible with the product and the other packaging items?
15.	Is the closure user-friendly?
16.	Is tamper evidence, child resistance or special handling required?

The list is far from exhaustive but serves to put into perspective the broad knowledge that will be required if the designer, technologist and brand managers are to work together to achieve a suitable closure for the product. Continual development is the lifeblood of the packaging industry, but it should be remembered that the basic principles that are used to push forward the frontiers of the technology are grounded on experience, knowledge and previous success.

1.5.3 Types of hazards for a container closure

The closure of the container must be able to protect the product and the environment in the same way as does the container. It would be of no use if the container protected the product, but the closure provided little or no protection. The hazards that are experienced in use vary with the product or the environment in which the product is expected to perform. Consideration will also be needed to protect or contain the product in the transient environments that may be encountered along the supply chain. A product going by sea, for example, from the northern hemisphere to the southern hemisphere, will need to be protected throughout its journey from the vast changes in temperature and humidity within the shipping container, as well as from the possibility of salt water exposure due to a poorly sealed container. Packs travelling from sea level to high altitude cities (such as Brasilia) will need to be protected from the pressure changes and the possible effect of low atmospheric pressure.

Thus, closures are subjected to many hazards and they must be able to protect the product whilst still perform their own functions of containment and delivery. A number of potential hazards are discussed in the following sections.

1.5.3.1 Biological hazards

Closures are more likely than the containers to be subjected to biological attack. Since, in the majority of closure systems, the product is at the interface between the bulk in the container and the environment in which the product is being used, the product is under attack from any contamination within the environment. Moulds, yeasts and microbes in the environment can multiply at alarming rates in closure delivery systems, thereby allowing the contaminated product to be dispensed with the next use of the product. Closures that allow the product to contaminate the outer surface of the closure may give rise to a serious biological hazard. Clean dispensing of the product is essential if a biological risk is present for the product, and the careful choice of materials may be necessary if a hazard is to be reduced or eliminated. The use of antimicrobial compounds within the closure material may be considered, but one should ascertain whether these materials are safe to use with the product (and legally permissible).

1.5.3.2 Moisture

This is one of the fundamental considerations for the closure system. Moisture is present within the atmosphere to varying degrees at different times of the year. It may be that because of the product characteristics, moisture may egress from the product under some conditions and ingress to the product under other climatic conditions; whichever pertains (egress or ingress) to a particular product, precautions need to be considered if the product is to remain in its saleable state.

1.5.3.3 Dust and dirt

These may sound reasonably harmless, but they are serious issues for the closure designer and specifier. Throughout the shelf life of the product, the closure will be stored in conditions where dust and dirt will have a detrimental effect. Dust and dirt not only have an effect on the consumer's willingness to purchase, but can have a serious effect on the efficiency of the closure system to operate effectively. Dirt entering the closure system will bring with it microbial infestation, and the resultant mix of product and microbial attack could be harmful to the product in use, as well as to the user. Dust and dirt can also come from the outer packaging that is used to transport the packs through the logistics systems. Fine particles of cardboard dust that rub off the outer packaging can contain enough moisture and nutrients to support microbial growth (especially in humid atmospheres), leading to a further hazard.

1.5.3.4 Light

The various wavelengths of light that are visible in the atmosphere (as well as those that are not) have differing effects upon various packaging materials. In addition, the colouring of materials with a range of colouring agents magnifies such effects. One should not assume that tests that have been carried out on a material, for example, with white pigmented materials, will have the same effect when using blue pigmented materials. Different pigments perform differently under different conditions. There have also been cases of pigments of the same colour reacting differently under different conditions. Moreover, some pigments may be more reactive to ultraviolet (UV) light, whereas others may be more reactive to infrared (IR) light – or indeed to other wavelengths of light in the visible spectrum. A case in point is with a hand cream container that was manufactured in white pigmented polyvinyl chloride (PVC); this yellowed when stored in the dark (in a sports bag or a corrugated cardboard box). However, when the container was re-introduced to the light, it reverted to a white-coloured container, over a period of hours. This reaction was directly contrary to what one might normally have predicted (non-reversible yellowing on exposure to light). An investigation of this phenomenon revealed that the particle size of the titanium dioxide (used in the white pigment) achieved this colour change in the dark, in the presence of phenols from the corrugated case or the items in the sports bag.

The container closure may also need to protect the product from harmful effects of both visible and invisible light (see Fig. 1.15), and pigmentation may be required to fulfil this function. Light can also have an effect on the closure material itself

Figure 1.15

and cause either shrinkage or hardening of the materials to such an extent that the closure becomes ineffective in storage or use.

1.5.3.5 Product interaction

Consideration must be given to the possibility of the closure materials interacting with the product and causing either an unsaleable product or leakage from the container in store. Different materials expand and contract at different rates and thus the potential for leakage may be different under variations in conditions experienced throughout the life of the container and closure system. The rate of uptake of a constituent in a product into the closure, or a component of the closure, may give rise to a differential expansion on vital components, making the closure ineffective. Where active ingredients in a product are adsorbed into a closure, then, although checks on the product in a shelf life test may show satisfactory results, the product may actually be less effective; this may occur during use, as the product ingredient comes into contact with the closure component and is adsorbed. The consequences may be that the expected dose is weaker than anticipated.

1.6 Manufacturing considerations

1.6.1 Machinery

Changes in the machinery used to produce and apply closures continues at a fast pace. The increase in the use of computer-aided controls and in the design of the machines to self-diagnose faults has lead to a growth in production speeds, with a decrease in the labour content required on the manufacturing or packing lines. Machine controls now allow several machines to be operated by one person with automatic fault diagnosis and line efficiency reporting. With new materials coming on-line, the processing machinery should become more adaptable to the requirements of several different materials. Downtime in changeover from one material (or mould set) to another has had to be reduced to the bear minimum and maintain the efficient output to offset the high cost of new equipment.

Robotics are commonly used to remove mouldings from machines and apply finishing operations (such as closing caps or adding wads) prior to the parts being packed. Other robotics will be used to transport the finished products to store and advise the location for future retrieval.

1.6.2 Closure handling

Many closures require a further operation prior to being used on a packing line. These operations may be the addition of a liner, closure of a cap or the assembly of other components such as the complex aerosol valve. Each additional operation adds cost to the final assembly, and much care is taken to reduce, as far as possible, the effects of these additional operations on costs. Careful design of the closure can have a significant effect on the cost of the final product. Once the closures are assembled, careful packing into transport containers is essential both for the safe arrival at the packing plant and for the efficient use on the packing line. Some components may be tumble packed into the transit outers where the use in the packing plant is by automatic machinery, or they may require careful stacking. However they are packed, it is essential that the transit container withstands the journey hazards that it will be subjected to.

1.6.3 Lightweighting

Lightweighting of all components must be considered seriously if the designers or technologists are to demonstrate that they have complied with the legislation on packaging use. This is well documented throughout the EU, and the requirements are likely to become more stringent as time progresses. Most countries have some sort of environmental legislation on packaging that evolves the use of the minimum amount of packaging for the effective and safe use of packaging.

1.6.4 Stock versus custom

There has always been much debate over the question whether to use a stock container and closure or to have a custom-made closure. If the answer were a simple one, then there would be no debate: indeed, the individual merits of each container and closure need to be considered and many factors come into play to make the correct decision. It also may be that the decision needs to be reviewed as the product changes in maturity on the market. All of the considerations outlined in this chapter need to be considered when deciding on the closure to use. Another factor would be the quantity of sales units that are expected to be sold. If the market is limited then the costs of development and commissioning a custom closure may well be prohibitive. The design costs for a custom closure could be an important factor in the development costs of the product/pack combination. In addition, it should be remembered that any testing of the product/pack combination should ideally be performed in the final pack that is proposed for the market. Any changes to the pack will introduce an extra element of risk of pack failure.

1.7 Legislation and testing

1.7.1 Legislation

Every industry has legislative considerations for its own products and the packaging materials that are used with the products. There is no industry that does not have to comply with legislative requirements for its products. Although every care may be taken to comply with the domestic requirements in the country of origin of the product, as soon as export is considered, further sets of requirements will need to be considered. Even if this is not the case with the product inside the pack, there may be additional requirements for the packaging alone. However, it is not possible to ignore the product when considering the pack, since the product and pack form a very intimate combination, which cannot be considered as isolated items. For example, in the case of a liquid product, one will need to consider the effect of the product on the pack and ask some of the following questions: Does it contain a volatile component? Is it flammable? Is it pressurised? Is it acidic or caustic? Is it sensitive to moisture ingress or egress? Is it light sensitive? Does the pack need support in transit or use? Is the closure system in need of protection in transit or use? Is tamper evidence needed? Is child resistance needed? Is openability for less able-bodied consumers required?

All of these questions, and more, would need to be answered before a pack recommendation could be made. Moreover, this process would need to be followed for each of the markets where the product is to be sold; specific packaging requirements for the individual markets would consequently also need to be assessed; finally, the individual country (or state) legislation for the product and its pack would also need to be considered.

A considerable amount of packing legislation focuses on environmental concerns, with relevant legislation encompassing issues of recycling, the reduction of waste and pollution and the sustainability of our natural resources, and these topics are covered in detail later in this chapter.

Perhaps the most prevalent type of legislation is concerned with issues around ‘safe’ packaging; however, safe packaging is viewed differently country by country, and sometimes also by neighbouring states. Even within the EU, the variations in legislative requirements for packaging vary from country to country. Given that there are approximately 200 countries in the world (and often numerous states or provinces within each) and that all have the potential to insist on their own set of legislations for specific products and packs, the problems of complying with all relevant legislations can considerably limit the possibilities open to packaging designers and manufacturers.

Fortunately, however, life is not quite as complicated as this; most products are not sold in every country, and not every country has its own legislation: many countries follow the lead of more developed countries in framing their packaging requirements. Different sets of previously discordant requirements are also becoming more synchronised as countries and legislative bodies realise the benefits of universal legislation and the globalisation of trade.

1.7.2 Testing

All packs and closures will require testing at some time during their evolution and production. It is important that this work is carried out both efficiently and effectively.

Testing can be considered as occurring in three distinct types – each of which has its own specific requirements. It is not the intention of this section to list all the different tests that may be carried out on a container and closure – such a list could easily fill this book and be irrelevant to many of the readers. What it will do is delineate the three main types of testing: (i) investigational testing, (ii) comparative testing and (iii) assessment, giving information on when and how the data thus collected should be used in the final pack specification.

With all testing, it is important that, wherever possible, standard tests are used to generate data. This allows the test results to be directly compared to results generated from previous experiments and/or from other researchers. There are a number of different standards' organisations, including the International Standards Organisation (ISO), the American Society for Testing and Material Standards (ASTM), the Deutsche Industrie Normen (DIN), the European Federation of Corrugated Board Manufacturers (FEFCO) and the Technical Association for the Pulp and Paper Industry (TAPPI), to name but a few.

As the above list suggests, there are international, as well as national, standards and these are complemented with standards from the various material categories, such as pulp and paper, plastics and glass. Certain market segments will also have defined standards to follow; one example of this is the pharmaceutical industry, where there are pharmacopoeias from various countries such as the United States, Europe and Japan. With the latter, these methods take priority over other standards, and it is important to understand and comply with the hierarchy of methods used in a given industry. Where there is product diversification, companies should ensure that they are aware of all appropriate legislation and standards, and, of course, they must ensure that they comply with these.

1.7.2.1 Investigational testing

Investigational testing is usually the province of research and development, where the investigators are looking for data that will allow them to say if the pack/closure is suitable for its intended function; the data that are collected are definitive and will be used to prove or disprove the hypothesis under investigation. Results should, therefore, ideally be in the form of unequivocal numerical data, since they will be used to form the basis of specification for both the purchase and the use for the container/closure.

1.7.2.2 Comparative testing

As the name suggests, this type of testing involves comparing one aspect of a closure against that of another closure: the type of question one would be expected to answer would be 'is sample A better than, equal to or worse than sample B?' If standardised test methods and procedures have been used to generate the investigational data, the experiment at this stage of testing should enable the researcher to concentrate the number of samples and tests around the expected end point.

1.7.2.3 Assessment testing

This type of testing is conducted in order to attempt to demonstrate that the samples meet the specification required. Typically, it will be performed when goods are produced, when they are received at the packers or as an in-process test during production. In each case, the critical question is 'do the components meet the specification?' This type of test will allow the researcher to give a definitive answer either way (i.e. 'yes, it does meet the specification' or 'no, it does not meet the specification').

Assessment testing allows the use of 'go/no go gauges' for rapid throughput of samples. An example of such a gauge would be a metal plug that will fit between the opposite threads of a screw closure, if the internal diameter is correct, but that will not fit if the internal diameter is too small. Similarly, the other end of the gauge would be such that it would not fit between the threads in a 'good' closure but will fit if the threads are too small (i.e. the diameter of the screw closure is greater than that allowed by the specification).

This type of testing is considerably quicker than taking measurements and allows a faster throughput of samples; measurements need to be taken only if the components 'fail' specification, and an investigation will then be initiated to determine the cause of failure.

Any 'on-line' or 'in-process' test should be developed to be as simple as possible – certainly, this is an area where go/no go gauges may be particularly useful. Further, when testing on-line, it is important to specify the time following sampling when the packs and/or closures should be tested; if this is not done, inconsistent results can be obtained, negating the validity of the results, and thus, the researcher will not have a sound basis on which to confirm or deny that the product tested is within its specification.

With all types of testing procedures, it is important that all parties involved (e.g. material suppliers, converters and packers) understand, and agree to, the methods and procedures being used to test the components. It is much easier, and more time efficient, to reach a consensus on the above at the beginning of development, than when an 'out-of-specification' delivery is sitting in the warehouse waiting to go into production.

All testing should be performed by personnel who have been suitably trained in the method, protocol and procedures that they are going to carry out. All equipment used should be suitably cared for and calibrated to ensure consistency of results; there are numerous test houses available that will help in this work if the expertise is not available in-house.

In addition, and wherever possible, all packaging components should be conditioned at a standard temperature and relative humidity for at least 24 hours before testing; this ensures that any expansion and/or contraction has taken place before testing and allows an easier comparison of results. All testing should also be carried out on sufficient quantities of samples, to give meaningful, reliable and valid results – this can be achieved through the use of statistical methods to ensure the appropriate design of experiments.

1.7.3 Child resistance

Legislation requires that certain packs (for example, certain pharmaceuticals and corrosive products) are placed in child resistance containers. As a consequence, a large variety of closures have been developed that purport to meet this need. Not surprisingly, some of these will work better than others, but it is not the liability of this chapter to pass judgement on particular types. The specifier and/or developer of the pack must ensure that they are satisfied that the system they have chosen both (i) meets the required standards and (ii) can be opened by the target market. The interested reader is referred to Chapter 2 of this book for a critical evaluation of the issues involved in taking into account human capabilities and behaviour when designing closures, and to Chapter 9 for a more in-depth look at child resistance, together with the related matter of tamper evidence.

1.8 Environmental considerations

Of course, vast savings can be made with the correct choice of the packaging medium and format; similarly, losses are inevitable if the wrong materials are used. It is of paramount importance that the designer and the user of the packaging are aware of the potential and the pitfalls of any packaging medium used, not only for the sake of their financial future, but also because it is true to state that the responsibility for the well-being of the community and of the environment rests with the packaging designer now, more than at any other time in the past.

Every technologist and marketing manager should, as a second nature, be aware of the environmental consequences of the packs that they place on the market. To be aware of the depletion of natural resources and of the effects of manufacture and disposal of the packaging should be a priority before the pack is placed on the market. It is one of the important questions that should be on the checklist at every stage of the process, from concept through to redesign.

Although each country has differing environmental legislation to contend with, and importing or exporting packaging and packed products may come within the confines of this legislation, there is a greater story that can be told if the total environmental effects are considered and documented prior to sale of the product to the final customer. If a company is ‘environmentally aware’, it has a strong story to tell to the consumer, and higher sales are likely (even at slight price disadvantage over a competitor product). The full cost to the environment of the package is very rarely considered since, after initial investigation, the major factors that affect the environmental cost are reasonably transparent.

1.8.1 Life cycle analysis

When assessing the environmental burden of a packaging system, the total life cycle should be examined. Life cycle analysis is sometimes also called ‘cradle to grave’ analysis; it emphasises the need to look at the environmental effects of the total life cycle of each item that is used. Thus, the cost of extraction and manufacture of the raw materials, transport and storage, manufacture, storage, transport, warehousing for a wholesaler, transport to a store, storage, in use costs and disposal costs must all be included in the equation. Certainly, the list is daunting. Moreover, one should also be aware that these costs will vary depending upon the country from which the materials are extracted manufactured, used, sold and disposed. For example, costs for electricity are different in Norway (which mainly uses hydroelectricity) as opposed to the United Kingdom (which mainly uses fossil fuels and derivatives). Final disposal costs vary from country to country depending upon the use of landfill or incineration.

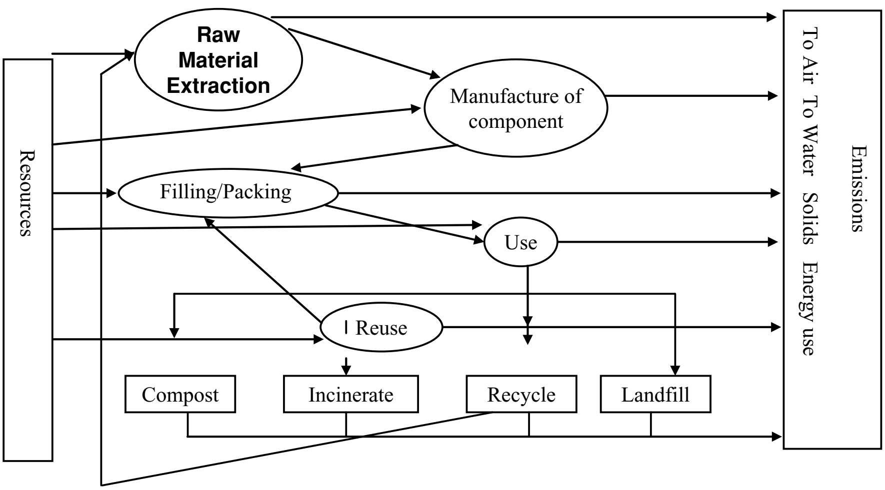

Figure 1.16 The life cycle of a packaging material.

The above diagram gives a very simplistic view of the life cycle process and leaves out, for the sake of clarity, transport and storage areas that also need to be considered as environmental costs. These considerations are as follows:

(1) The use of non-renewable resources.
(2) The costs of extraction and the resultant waste products from extraction.
(3) Storage costs for the raw materials (before dispatch to the processor).
(4) The transport of the raw materials for processing.
(5) Storage of materials prior to processing (at the processor's site).
(6) The processing costs to change the materials into a finished packaging component.
(7) The storage of finished components prior to shipment to the packer.
(8) Transport of components to the packer.
(9) Storage of components at the packer plant.

(10) Packing costs.
(11) Storage of packed product.
(12) Transport to the wholesaler.
(13) Storage at the wholesaler.
(14) Transport to the retail store.
(15) Storage at the retail store.
(16) Transport to the user.
(17) User costs.
(18) Disposal after use (through the disposal chain).

Each of the above has an environmental cost that should be considered when making a life cycle analysis. For components coming from different suppliers, the environmental cost may well be different as the methods of transport and storage costs will be different, even if the end component is the same. Wastage rates will be different, as will the energy costs and the transport costs, depending on the method of transport and the journey length.

1.8.2 The basic 'rules' for the environmental considerations

These can be summed up into the four Rs: Recycle, Reuse, Reduce and Recover.

1.8.2.1 Recycle

This term delineates the ability of the packaging material to be taken back into the chain and be recycled into its basic resin format for further use as another container (although not necessarily for the same use as the original container). Many countries advocate the use of recycling for their growing packaging mountains. The technologist has a major problem in this respect, with many consumers unable, or apathetic, to identify the materials that are being used and to sort the 'waste' into the various waste stream categories. Containers that are made from more than one material (and here the various plastic materials should all be classed as different materials) are difficult to reprocess into their various waste streams. Some recycling plants are capable of segregating the different forms of plastics but the costs are still high and mainly uneconomic.

1.8.2.2 Reuse

In this section, we are looking at the reuse of the container for its original purpose. The classic example is the glass milk bottle, which is (with increasing rarity) delivered to the doorstep. The bottle was originally designed to last for 40 trips, but with lightweighting (see Section 1.8.2.3 below) the number of trips has been reduced. Reuse is not without its own environmental burden, since chemicals and water are needed for the cleaning processes prior to refilling. Other considerations could manifest as a pack that is capable of being refilled using a specific refill pack, where the refill pack would then become the packaging waste, rather than the original pack.

Of course, many other packages can be considered for reuse, albeit not for their original purpose. For example, there is a pump spray pack used for furniture polish, which can be *reused* as a spray for plants in the greenhouse.

1.8.2.3 Reduce

This is an area to which some consideration should be given at the start of any project. Any rational technologist would use only the minimum material sufficient to carry out the specific functions required, safely and efficiently; however, it makes reducing the material content of the pack very difficult, and yet, it should not be forgotten that new developments in materials and packing line equipment might allow for material reductions throughout the life of a product. Constant vigilance should be maintained to ensure that all packaging for all products are using the minimum necessary to perform their functions.

1.8.2.4 Recover

This may sound the same as 'recycle', but it is not. 'Recover' involves the recovery of the energy used in the manufacture of the packaging materials; this may be in the form of incineration (with heat recovery) or composting, where the breakdown gases are recovered to transform into heat or electricity generation. It should be noted that both these methods have their own problem generation: incineration can result in high levels of atmospheric pollution and the generation of greenhouse gasses or dioxins – and both of these are harmful to the planet's ecosystem. Composting, even with the collection of the gases produced, gives rise to a problem of the residue from the composted products; these can have higher levels than normal of heavy metals and thus be unsuitable for land fertilisation.

Any of the above methods is preferable to land fill, given that some of the material or energy used to manufacture the products can be reused. With landfill, none of the materials can be reused, and there is a high risk of contamination of the ground water from the leachate or of the atmosphere from the gases produced from the decomposition. The land area is also unstable and polluted for many years after the land fill site is full, and indeed a good packaging technologist should also be aware of the problem areas for the environment and what needs to be considered with respect to giving the earth's ecosystems the best possible chance of recovering – and running – naturally.

Different countries are now introducing various areas where there is a legal responsibility for the packer to consider the environmental aspects of the pack and of its disposal. Penalties can be high, since much of the legislation is being introduced under the criminal codes rather than under a civil code. This allows for the prosecution, not only of the company, but also of the individuals within the company who have responsibility for placing the packaging on the market. This could be the packaging technologist, the marketing manager or even the company director. Nobody is immune if it can be shown that they did not take adequate steps to ensure that an offending pack was not placed on the market. Good record keeping is therefore essential, and reasons for decisions need to be recorded if a possible prosecution is to be avoided.

Many of the world's environmental problems have at various times been attributed to the packaging industry – an easy target since, for many years, the packaging industry fragmented itself in order to gain market share over the rival offerings. Paper showed its credentials over the plastics alternatives, and the various plastics competed for their share by 'knocking' the other plastics forms in the environmental stakes. Today, more than ever, the industry is showing a united front, with pressure being put on the misdirection of the over-packaging lobby to blame the packaging industry for all the ills of the environment that occur. The industry, it is fair to say, is not whiter than white, but, with a more united front within the packaging web, and consequently, more time and effort being directed towards managing environmental issues *outside* the world of packaging, the huge gap between the reality and the misinformed and/or ignorant perceptions and attitudes of the general public may begin to close. When this happens, a real dialogue can begin to take place between consumers and the packaging industry, and the environmentally minded consumer can begin to feel more confident that their purchasing behaviours will result in genuine benefits to the environment.

1.9 Conclusion

In conclusion, this chapter has introduced many of the aspects that need to be considered when a closure is being considered; each type of closure system – from sealing film to screw-capped containers – will require a different solution, and all will have some aspects of the above considerations in common. The following chapters look at the practicalities and issues with many of the most common sealing and closure systems currently in use. Although it is likely that readers will select particular chapters that are of direct relevance to their current industry, I would urge everyone to read and consider Chapter 2 – the design and psychology of closures – as this is relevant to all industries.

2 The design of packaging closures

Belinda Winder

2.1 Introduction

2.1.1 Overview of chapter

Although this chapter is entitled 'the design of packaging closures', a far more appropriate appellation would be 'the design of packaging openings'. Indeed, the nature of much of my work in the packaging domain has been to attempt to push the packaging industry (sometimes kicking and screaming) into looking at the design of packaging from the perspective of consumers *opening* the packaging, rather than from the packaging industry's viewpoint, where discussions are very much in terms of the *closures* involved – a subtle but telling distinction in perspective that in many ways epitomises the plethora of design problems that need to be addressed by the packaging industry.

This chapter will begin with an introductory overview of the challenges faced by the packaging industry; there follow sections on ergonomics and the science of design; an analysis of the relevant physical, cognitive and psychometric constraints that affect the capabilities, attitudes and behaviours of human beings opening and using packaging; and, finally, a focus on the packaging itself, including a brief overview of the differing problems associated with various types of packaging materials and a research-based explanation of consumers' ability (or failure) to use a number of packaging aids. The chapter concludes with a look at packaging from the consumer's perspective and the delineation of a set of criteria and guidelines developed as a result of my psychological studies. It is hoped that these will prove helpful to anyone involved in the design of packaging and packaging closures.

2.1.2 The many faces of packaging

Almost every item that one can imagine in one's home has arrived in packaging. Indeed, packaging can be envisaged as the key vehicle in the passage of almost every product as it makes its journey from its original point of manufacture to the point of consumption in our homes or elsewhere. Before it reaches its final destination, domestic packaging is filtered through a chain of users, and each user within the chain – manufacturer, distributor, retailer and purchaser – has different requirements that the packaging must fulfil (Paine, 1991). Thus, packaging has many purposes, not all of which are immediately (or indeed ever) obvious to the average consumer. This (often understandable) ignorance, together with the inconsistent and irrational choices that, as consumers, many of us display, can leave the packaging and retail industry bewildered as to exactly what the consumer wants – if people say they want eco-friendly, non-excessive packaging, why do they flock to buy the products that are anything but?

2.1.2.1 Functions of packaging

The range of functions that packaging needs to fulfil has been identified as openability; usability; protection for transportation; containment of product and multiple products; prevention of the contamination of goods by their surroundings, or vice versa; identification of manufacturer and origin; safety and tamper evident features; labelling information (including nutritional and legal information, instructions for opening the packaging and storing/cooking/serving the products, recycling information); storage and preservation for long-life products; facilitation of transportation (whether by consumers, or earlier in the supply chain); marketing and brand advertising.

The amount of packaging required everywhere everyday is immense – in 1998, over 30 000 different products were available from the shelves, freezers and aisles of supermarkets and department stores, mass merchandisers and speciality stores (Meyers and Lubliner, 1998). Nowadays, the industry has surpassed this figure twice over, and thousands of new products with increasingly diverse shapes, sizes and closures are introduced into the market each year. Although packaging in itself may amount to only a small percentage of the core cost of the entire product, it has, until recent years, been a favourite target for profit-hungry, cost-cutting retailers. Increasingly however, packaging, as well as the value that a good design can add to a product, has been becoming more noticeable. It is hoped that, in recognition of this, manufacturers and retailers who wish to upgrade their packaging designs to capture some of this extra value will use the opportunity to improve packaging at all levels, and not simply focus on the more superficial marketing using attention-grabbing re-designs.

2.1.3 Openability and usability

The use of packaging by the consumer goes through seven stages: initial opening, use, closure, re-opening, re-use, re-closure and disposal. Initial opening accounts for 39% of the reported accidents involving packaging and thus appears to present the most problems (Strauss, 2001). The Swedish Packaging Research Institute (Berns, 1981) identified two basic problem areas in packaging openability: (i) inadequate, incomprehensible or misleading opening instructions and (ii) problems related to the handling of packaging and the consumer's interaction with it, the latter generally focusing around problems with consumers attempting to open the packaging which they are not physically capable of doing in a controlled or safe manner.

Openability can be defined apropos domestic packaging in terms of packaging closures that can be opened within a reasonable time, using a tool (where indicated and appropriate), with minimal risk of injury to consumers. Usability can thus be defined as that which provides convenient access to the product, and the consumer–product interaction underlying usability has been posited to consist of four main factors: execution time, learning time, consistency and effort (Eberts, 1997). Thus, according to Eberts, a product designed with good usability would be the one that consumers could learn how to open and use quickly and easily; the operations so learned (to open and use the product) would consistently produce the same result and with little effort.

2.2 Scope of the problem

2.2.1 Accidents and injuries

Re-thinking the design of closures is not just about reducing the number of accidents and injuries caused by domestic packaging, although this should, by necessity, be one of the most urgent motivators. Indeed, the last official count carried out in the United Kingdom by the Department of Trade and Industry (DTI) in 1997 (note: the DTI no longer collects these data and thus no updated figures are available) stated that over 94 000 people (this number comprises 66 889 non-medicine packaging-related accidents and 27 425 medicine packaging-related accidents) were admitted to the accident and emergency departments of hospitals in the United Kingdom in 1 year alone as a result of packaging-related accidents or injuries (DTI, 1997a). Yet my research shows that this is a gross under-representation of the problems with domestic packaging as a whole. Indeed, this figure has been described as ‘only the tip of the iceberg’, with the DTI reporting that only one-third of all packaging accidents are actually reported, the remaining two-thirds being treated at home. The research that we conducted over the last few years (Winder et al., 2002) on several thousand participants, ranging in age from 10 to 82 years, echoes the DTI findings, with the majority of participants we spoke to affirming that they had never bothered to report, or seek help for, accidents or injuries incurred while opening, using or disposing of packaging.

The DTI data reported that, for non-medical packaging, 26 187 (28%) of accidents occurred during initial opening, 14 839 (16%) on re-opening and 25 862 (27%) at after-use/disposal. Of the accidents occurring with medical packaging, 27 425 (29%) were classified as occurring on re-opening of the closures (which is, in effect, 100% of the accidents reported with medical packaging).

The most frequently reported packaging-related injuries are cuts and lacerations from the inappropriate use of knives to open ‘stubborn’ packaging, or muscular strains sustained in attempting to open jars and bottles. These two types of injuries are generally dealt with by consumers at home, where, in most cases, medical help is seen as redundant. Other injuries suffered attempting to open and use problematic packaging include broken teeth and knife wounds (Strauss, 2001) as well as severe muscle injuries and strains, burns and scalding, and even temporary blindness.

Accident scenarios related to me while conducting this research even included an instance of packaging-related whiplash, the latter being an injury brought about by desperate driving of an anxious spouse on their way to the accident and emergency department of a local hospital, following an unfortunate incident with a sharp knife. The knife had been used to open a medical container with a child-resistant closure (CRC). The latter had unwisely stood between the consumer and their much-needed migraine tablets and this desperate migraine sufferer was reduced to attempting to open the stubborn CRC by sawing the top off with a sharp blade in the dark (due to their extreme sensitivity to light). This might sound extreme but my research repeatedly revealed the extraordinary lengths people would resort to in order to 'conquer' a stubborn piece of packaging.

With cases like that above, it is perhaps not surprising that costs to the UK National Health Service are estimated to be in excess of £10 million for packaging-related injuries (Norris and Wilson, 1999). Yet, it is clear that only the most severe injuries and/or those that involve vulnerable consumers, such as children, will precipitate an emergency visit to hospital; the overwhelming majority of packaging-related accidents go unreported.

2.2.2 Child-resistant closures

There is one particular type of packaging-related accident that invariably results in the potential victim being taken to hospital, that is, in cases where poisoning is suspected. Records indicate that 32% of the reported accidents involving pharmaceutical products resulted in the victim being admitted as an in-patient (DTI, 1997a). In comparison, accidents that involved non-medicinal packaging resulted in a 4.8% reported rate of hospitalisation. Of the total number of hospital admissions for packaging-related accidents, 73% were in respect of accidents involving the re-opening of medical packaging. These accidents are not really caused by the packaging material itself (in the same way that a sharp metal edge or broken glass might be a direct cause of material-related accidents) but arise from the potentially toxic contents of the packaging, together with inadequacies and/or shortcomings in the design of CRCs that are utilised for medical and household cleaning products. Of course, CRCs have been incorporated into the design of medicine and household products with the absolute intention of reducing such accidents. However, the continuing occurrence of these poisoning accidents, together with consumers' self-reported (and potentially dangerous) behaviours with CRCs and medicines generally, suggests fundamental flaws in the thinking behind the design of CRCs.

2.2.2.1 Child (and adult?)-proof closures

European legislation requires that for a packaging closure to be deemed child resistant, it must be tested sequentially upon a group of 200 children aged between 42 and 51 months. The participating children are given five minutes to attempt to open the packaging closure, without the benefit of any instructions or help. Any children who fail to open the closure in this time are subsequently given a silent demonstration of how to open the packaging, by an adult, and are then allowed a further five minutes to attempt to open the packaging. A closure is deemed child resistant if 85% of the child test panel have failed to open the packaging closure by the end of the ten-minute testing session.

In addition to the tests on children, the legislation provides an opportunity for an adult panel, consisting of 100 participants aged between 50 and 70 years, to attempt to open the packaging. In contrast with the child test group, adult participants are required to assess whether the CRC can actually be opened by those who need to access the contents of the packaging. The adult test group must be able to open the closure within 60 seconds, without the benefit of a demonstration, for the closure to be classified as usable (Wilkins, 1998). Thus, the test procedures were designed to ensure that CRCs were difficult for children to access but easy for adults to open and utilise (Jenkins and Osborn, 1993).

However, the stringency of the adult test procedure differs significantly from that of the children's, in that any adult suffering from a physical disability, or who experiences great difficulty in using the product during an initial period of familiarisation, may, at the experimenter's discretion, be excluded from the entire testing procedure. It could be argued that it is precisely these adults – who may legitimately be excluded from the tests – who should be used to test the accessibility of CRCs. Indeed, our own research indicated that the majority of openability problems with CRCs were caused by the lack of physical strength needed to carry out the requisite motor functions to open these closures. Rather ominously, consumers happily reported resorting to a number of unsafe behaviours as a direct result of their inability to open CRCs, including the decanting of medicines into other, easier-to-open, containers; leaving off the top of the original child-resistant container; or even simply emptying the medicine into a bag or bedside drawer. Thus, the safety tests that CRCs need to pass are clearly well intentioned, but in practice they encourage the designers of such closures to produce CRCs that are too physically demanding for children to open (since the cost of testing any potential new CRC is high) and this is a 'safe' option, particularly for the comparatively low priority that is given to testing openability with the adult test group. My own conclusions were that CRCs should be designed to be *cognitively* difficult rather than *physically* difficult to open and, together with Factory Design, I have developed some novel CRC designs that reflect this approach (note: the interested reader may refer to Factory Design (www.factorydesign.co.uk/) or the Faraday Packaging Partnership for further details regarding this project).

2.2.3 Quality of life

Packaging is an important part of everyday life – it incorporates sustenance, health and hygiene as well as enjoyment and leisure. The effects of problematic packaging on people's quality of life are not simply confined to potential injuries. Indeed, physical hurt to the person is comparatively rare, in comparison with the other effects of poorly designed packaging closures: outcomes that include the spillage and waste of products, necessitating the expenditure of time and effort to deal with the consequences, in addition to the financial cost of having to re-purchase the product; frustration that is magnified and exacerbated with successive problems, potentially generating emotional anxiety and a negative mood state. Indeed, some of the most influential effects on consumers' quality of life are psychological, with a loss of autonomy and low self-esteem, brought about by failures to open and use packaging. An individual's diet and lifestyle can be deleteriously affected by a restriction in the products that he or she can access and use. In each case, there will be both financial and/or emotional costs to the consumer.

2.2.4 Age and health

Age can have a severe impact on an individual's ability to access and use packaging. In the United Kingdom alone, there are nearly 10 million people aged 65 or older, and the trend to live longer is set to continue – by 2025, life expectancy will have risen to 85 years for men and nearly 93 years for women. By 2050, the number of people in the world aged 60 years and older will triple to more than 2 billion people.

Although many older people remain fit and healthy, inevitably they will experience a loss of physical strength and power, and many will also be affected by conditions such as osteoporosis, arthritis and impaired sight and hearing. However, it is not just older people who suffer disabilities; the American Community Survey (2003) reported that of the 283 million people in the United States in 2003, the number of people with disabilities amount to over 77 million (note: the American Community Survey (ACS) is limited to the household population and excludes people living in institutions, college dormitories and other group quarters). Of this, only over 28 million comprised people aged 65 years and older. Thus, although some level of disability may be a natural consequence of living longer, the majority of consumers with disabilities do not fit the expected model of an ageing, grey-haired consumer.

There is a huge and vociferous population of these so-called minority groups who suffer most with poorly designed packaging, but who would be very willing to help the packaging industry with some self-evident (to them, at least) suggestions for improving the openability and usability of packaging for all consumers. For example, many food products, household detergents and medicines come in containers with a closure that requires a 'grip-and-twist' action to open. This is one of the foremost actions that proves difficult for people with arthritis or other disabilities that result in weakened or painful joints. Research has also demonstrated that the motor functions of *turning* and *pressing* require the most strength from people (Berns, 1981), and yet one of the most prevalent types of CRC utilises this very mechanism.

Additional consequences of age and/or disability can be more far reaching than just problems with opening and using packaging. Designers fail to take into account the fact that products may be designed and tested in ideal lighting conditions, by people with good (or corrected) visual acuity. In real life, consumers may not always have the right glasses nearby (or be wearing them while shopping) and products in similar-looking containers, or with instructions or labelling information written in a very small font, may lead potentially to negative consequences for people with anything less than perfect vision.

It is essential that the increasing proportion of our population that is elderly (and/or infirm) is able to maintain quality of life through the opportunity to make dietary and lifestyle choices from the entire range of products available, without worrying whether they will actually be able to open the packaging when they get it home. Packaging closures should be inclusive in their design; to do otherwise would seem to detract from the basic human rights of any consumer whose quality of life was deleteriously affected by the lack of forethought or consideration on the part of designers.

2.2.5 Social responsibility

Further and, perhaps in many instances, more crucially, there is a need for packaging to be designed within its proper context, and assessed and analysed for relevant social or psychological factors that may affect an individual's interaction with the packaged product in question. Thus, improving the design of packaging is not simply a question of reducing injuries and accidents – or even of enriching quality of life in terms of what may be deemed more consumer-driven factors, or of making allowances for age and disability – but demands an understanding of the deleterious effects that poor packaging can have on everybody's lifestyle and health. The industry needs to demonstrate social responsibility by actively addressing critical packaging-related issues, such as the problem of patient non-compliance with medicines, improving consumer attitudes (and behaviours) in terms of environmentally friendly disposal of packaging and minimising errors in consumers' understanding of product labelling (for example, in assessing safe product life and storage conditions and the maintenance or adoption of more healthy lifestyles).

Designers and manufacturers of packaging closures must also take into account the social responsibility they have to ensure, for example, their packaging does not appeal to inappropriate target groups (such as was the case with many Alcopop drinks that previously used very brightly coloured packaging, a magnet for children and under-age drinkers). Other potential issues include ensuring that, despite the occasionally minimal amount of space available on packaging for product instructions, care is taken to ensure that all consumers, particularly the partially sighted, or those who might prepare food without wearing their glasses, are alerted to any possible dangers in terms of food storage and safety instructions.

In addition, the existence or casual acceptance of persistent, but incorrect, attitudes to the cooking or storage of particular foods, which may result in anything from a slightly inedible meal to the very real risk of severe food poisoning, needs to be addressed at the initial packaging design stage by socially responsible packaging manufacturers and designers. The packaging industry has a duty to consider the consequences of consumers' attitudes and behaviours to the products their packaging contains, and to take this into account as an integral part of the design process itself.

2.2.6 *Environmental issues*

Consumers are extremely cynical about the packaging industry's perceived attempts to be environmentally friendly. Meanwhile, packaging manufacturers feel that any ecological advances they make either go unnoticed or are treated with suspicion by the majority of consumers – consumers who are vociferous in their calls for the packaging industry to be environmentally friendly, but who cannot actually be bothered to recycle their own domestic packaging waste.

The problem is that the packaging industry is caught on a two-edged sword, with the increasing environmental awareness of consumers and their dislike and cynicism of excessive packaging. Yet, on the other hand, the packaging industry still has to deal with consumer ignorance and naivety in terms of the differing amounts of packaging required to display products with 'minimal' packaging as per consumers' desires, in contrast with the quantitatively less packaging overall needed to display products in a way that attracts consumer criticism for excessive packaging.

In addition, it is true to say that consumers seem generally happy to throw the idea of excessive packaging out the window when it comes to themselves or certain products. My experience during (UK) National Science week, which takes place around Easter time, and during which, as part of a series of lectures designed to make some areas of academic research accessible to children, teachers and parents alike, members of the audience (mainly children) would be offered the chance to choose between Easter eggs packaged in excessively large boxes, compared with more discrete packaging (with the same egg inside). The only winners were the eggs in excessive packaging. Although this was true with children, it is also fair to say that we found the same results when testing adults too. This is clearly an area in which the education of consumers is needed to help the packaging industry act in a more environmentally friendly manner, without suffering a loss in business following from consumers *not* behaving in a dissonant manner to their (apparently) environmentally conscious attitudes.

2.2.7 *Aesthetics and fun*

Packaging closures can be fun to open! Our own research demonstrated the extent to which aesthetically pleasing packaging can contribute to people's enjoyment and quality of life. Re-designs that add a fun factor (see Winder (2002a, 2002b) for results of a number of studies exploring this topic) to packaging closures can be seen to reap tremendous financial rewards, both in terms of net profit and brand image.

2.3 Ergonomics and the science of design

Sanders and McCormick (1992) have asserted that one of the main objectives of the science of ergonomics (or human factors) is 'to enhance certain desirable human values, including improved safety, reduced fatigue and stress, increased comfort, greater user acceptance, increased job satisfaction, and improved quality of life' and that the approach of human factors necessarily relies upon 'the systematic application of relevant information about human capabilities, limitations, characteristics, behaviour, and motivation to the design of things and procedures people use'. There is necessarily an emphasis on the use of empirical data, and a reliance on scientific method and the consideration of objective data as an essential part of the design process. The data used in ergonomic design may come from a broad spectrum of data collection methodologies, including accident/injury records (a good source of information but entail the under-reporting of problems); the use of anthropometric data (involving the quantitative measurement of the human body, or aspects thereof); direct observation of user with product (this should be carried out by skilled experimenters who are preferably not associated with the manufacture or manufacturer of the product); interviews with users; quantitative surveys of the target population; usability tests; as well as more qualitative, open-ended types of research, such as focus groups (although in the latter case, there are numerous problems in terms of response biases and group effects which will severely bias the results unless they are anticipated and managed through the adoption of a rigorous and systematic methodology).

2.3.1 Inclusive design

An ergonomic approach to the design of packaging would involve evaluation of the many functions a package must perform and the actions and capabilities of the end user (Arnold, 1990). Such an approach would result in a product that is convenient for the end user and that should satisfy most of the consumer's needs (Kwon, 1999). However, part of the problem is that, as discussed previously, packaging has many users and many functions to fulfil. Unfortunately, this will result in some users and functions being given less consideration than others (Arnold, 1990). For example, Winder et al. (2002) found that left-handed individuals reported significantly greater numbers of accidents with packaging than did right-handed individuals. Such a result indicates that most packaging is designed for the right-handed majority, producing problems for the left-handed minority who nevertheless comprise 10–15% of the general population. To combat this, the ideal design scenario would be to design for the weakest or most disadvantaged portion of the population, i.e. females, older consumers, left-handed people, as well as for those with any disabilities that might colour their ability to open and use packaging, given that any design accommodating these groups will also accommodate and include the rest of the population. However, manufacturing costs may make such a scenario economically unfeasible (Arnold, 1990), until a major re-design or re-launch of a product is required.

2.3.2 The design process

Designers initially produce a conceptual model of the product that they intend to create, the 'design model'. This represents, or rather includes, the designer's understanding of the functions that an object must perform. The design model is said to be communicated through the *system image*, which is the end product of the designer's work. Users of the product develop a mental model (user's model) through their interaction with the product, and this manifests as the user's understanding of, and ability to use, the product. Designers will generally assume that the user's model matches their own system image, but this may not be the case. If the design model is not comprehensible to the user through the medium of the product, in the case of packaging and indeed anything else, then accidents and frustration may result. One explanation for user difficulties in comprehending the design model is that the time spent developing and working with the product allows designers to gain a high level of expertise when dealing with it. This expertise can lead to the generation of a product-opening mechanism that is incomprehensible to consumers with no prior experience of the product. Thus, a mismatch may occur through the designer's closeness to a product.

2.3.3 Good design – a consequence of good designers?

A good design thus depends upon the designer amalgamating the product features, user characteristics, use and environmental factors to assess the product–user interaction, producing a design that is suitable for all consumers. As Keates and Clarkson (2003) affirm "inclusive design, universal design and universal access are long standing, familiar terms with clear and laudable goals. However, their teaching and industrial uptake has been very limited. Many products still exclude users unnecessarily for reasons ranging from corporate insensitivity and the size of the market for inclusive products to the individual designer's inability to design them."

Each step of packaging design, whether concerned with appearance, functionality or production, can impact upon the success or failure of the product (Meyers and Lubliner, 1998). Thus, when designing packaging, designers should try to reflect on the need to make it easy to determine what actions are possible to open the packaging and to evaluate the state of the product. In Norman's (1988a) words, they need to "make sure that (a) the user can figure out what to do, and (b) the user can tell what is going on." Well-designed packaging should be easy to interpret and understand; it should contain visible clues to its requisite opening method; and, where possible, feedback (such as the sound of a seal breaking) should support and facilitate the correct opening and use of the packaging in question.

2.3.4 Function versus form

Of course, the consideration of aesthetics is also essential for many types of packaging. The packaging should ideally be attractive and unique to differentiate it from the products around it. However, aesthetics need not be sacrificed for usability, which can be inbuilt from the first conceptualisation of the product. As Norman states “if everyday designs were ruled by aesthetics, life might be more pleasing to the eye but less comfortable; if ruled by usability, it might be more comfortable but uglier. If cost or ease of manufacture dominated, products might not be attractive, functional or durable.”

2.4 Physical constraints and issues

Designers instinctively plan for able-bodied users and rarely incorporate the needs of less capable users into the design. However, what many designers fail to realise is that the so-called impaired users are *not* an alien species, requiring a vastly different design from that required for the so-called ‘normal’ users. Impaired users are just at the other end of a long spectrum of different abilities. What might be impossible for an impaired consumer to open, will probably also be difficult (albeit possibly only annoying for a young and healthy able-bodied male) for other consumers to open.

2.4.1 Age

Our research indicated that age correlated significantly with the level and variety of problems experienced when trying to open packaging, in every category of packaging that was assessed (tinned goods, tinned goods with ring pull, cans, plastic bottles and jars, glass bottles and jars, cartons/boxes, flexible packaging and tray goods), the only exception being in the category of *tray goods*. With respect to the latter, it should be pointed out that older people, particularly those aged over 60 years, are significantly less likely to purchase such products, damning them either as ‘a waste of money’ and/or as ‘too flimsy to hold or serve’.

In particular, age as a variable has a significant impact on self-reported ability to open tins with ring pulls as well as to open canned goods generally. This data suggest that the motion of utilising one finger in order to open packaging is particularly difficult for the elderly.

The day-to-day difficulties that many older consumers face when opening packaging are amplified to the point where a significant number of people cannot actually get to the food. The Helen Hamlyn Research Centre (2004) estimates that nearly one in five people aged over 55 years have stopped buying certain products because of difficulties in opening their packaging. This equates to nearly three million people in the United Kingdom – a large slice of the consumer market indeed.

2.4.2 Physical strength

The usability of a product is said to be measured, in part, by the degree of effort that must be expended by all users of that product during the processes of its usage (Eberts, 1997). One indication of the level of effort required is the degree of strength required to be expended by an individual to overcome the opening torque of a package (Berns, 1981). Research has shown that some of the most frequently reported problems with openability are due to the opening torque needed to access both plastic and glass bottles (DTI, 1997b, 1997c). Our own research has shown (for example, Nelson, 2004) that females find packaging that requires a great deal of grip strength more difficult to open than do males. However, it is not simply a gender difference that exists. In fact, grip strength, irrespective of gender, predicts difficulties in opening packaging, such that a low level of grip strength will be associated with a high level of reported problems when a consumer is attempting to open and utilise packaging; this suggests that people with weak grip strength are at an immediate disadvantage when opening many types of packaging.

2.4.3 Motor functions and child-resistant closures

Apropos CRCs, 90% of the consumers studied (and remember, we were studying a relatively 'young' subject group) reported difficulties while opening CRCs. Given that we found a significant positive correlation between consumers' age and the extent of their difficulties in opening the CRC ($r = 0.331$, $n = 100$, $p = 0.001$), it seems that by the age of 50, an average person can expect to have 'frequent' problems trying to open this type of packaging. As proposed previously in this chapter, designs should not rely on the need for physical strength to get them through the safety-testing regulations. Unfortunately, the motor functions of *turn* and *press*, two of the most common CRCs, necessitate pressing and/or turning actions, which thereby require the most strength from packaging users (Berns, 1981). Older consumers spoke at length about the problems they had trying to open both types of closures. The physical strength and/or manual dexterity involved in opening these CRCs necessitated the investment of both time and energy, often at a time when people were feeling less capable than usual (and thus needed to take their treatment). Instead, designers should explore opening mechanisms that require one or two physically undemanding actions – actions that are easy for the older consumer but that are nonetheless too sophisticated for 0- to 4-year olds to chance upon by accident.

2.4.4 Disability

Disabilities, such as arthritis, that weaken grip strength and restrict other motor functions also make the opening of packaging difficult. One of the key problems here is that the packaging industries when calculating the requisite strength for opening their packaging focus on torque targets that apply, in reality, only to a rather narrowed range of adults, since the anthropometric data that designers may utilise have a tendency to overestimate human capabilities, such as strength.

Thus, the target opening torque for bottles, jars and other type of packaging should be significantly reduced in order to accommodate the needs of consumers who are affected (either permanently or temporarily) by some type of disability.

Visual disabilities (for example, short sightedness, long sightedness) from which the majority of people suffer will also affect our ability to open closures. An example of this is demonstrated by the type of CRC that requires the user to 'line up two arrows and pull/push'. Although this particular type of CRC received fewer complaints than the two other most prominent designs, some of our participants highlighted the fact that their reduced visual acuity significantly impaired the ease with which they could perform the task of 'lining up the arrows' (and thus open the closure). As one participant indignantly stated, "I can't even see the arrows, let alone line them up!"

Consumers with less than perfect visual acuity also reported difficulties in reading opening instructions and other labelling information, and even in recognising items at the point of purchase. Since packaging manufacturers are being hard pushed to fit all the necessary labelling information onto packaging, other methods of providing necessary information (for example, through the widespread establishment and use of universal symbols to eliminate the need for several lines of text, or through the use of novel technology at the point of purchase as an aid to consumers who wish to avoid purchasing products that contain potential allergens) are needed to help packaging companies fulfil all their obligations with respect to legislation while making the packaging user-friendly for all. Figure 2.1 shows a number of health-related

Figure 2.1 An example of where symbols speak louder than words!

products that make use of the 'flammable' symbol that transcends most written languages. The symbol has been given an orange tinge to warn consumers, even on a subconscious level, that there is some element of danger in the use of this product – colour is a very powerful stimulus for humans and is a good place to start when developing universal symbols, although cultural differences in the use of colour should be taken into account when doing so.

2.5 Cognitive constraints and issues

Although it may be difficult to believe at times, the workings of the human mind are more intricate and complex than even the most complicated and advanced computer. Scientists working in the field of artificial intelligence still appear to be a long way from developing computer programmes that can display the kind of creativity, flexibility and intelligence that are a mark of the human species. In fact, many of the basic cognitive processes underlying these achievements are concerned with problem-solving processes (Newell and Simon, 1972). In other words, human beings have evolved with an innate desire to make sense of the world they live in, to recognise each and every thing in their environment and to make sense of the world around them. Given just the smallest piece of information, our minds will begin to start analysing the 'why', 'how' and 'what' of anything put in front of us, integrating the results of our search with what we already have stored in our memory.

Cognitive psychology allows us to gain an understanding of the way in which our brains process information: the retrieval of information from the outside world; the ways in which we try to make sense of this information; and ultimately how this information affects our behaviours – for example, when faced with packaging that we wish to open and use. The most relevant aspects of cognitive psychology that relate to how we open and use packaging are sensation and perception, affordances and attention and information processing. The final area that will be considered, which is related to human cognitive processes, is the predictability of human errors (mistakes and slips) and what research in this area can teach us about how to improve the design of packaging closures.

2.5.1 Sensation and perception

The initial step in our retrieval of information from the outer world is through *sensation*, which refers to the immediate response of our sensory receptors, located in our ears, eyes, nose, tongue and skin. As soon as we receive input from any of these senses, higher order cognitive processes jump into action, and we 'perceive' this input. Perception differs from sensation in that it is where we (generally on a subconscious level) organise and interpret the incoming data. It is the point at which the raw sensory information is given meaning and is dependent on the individual, with his or her differing experiences, abilities, culture and expectations, or even the emotion that the opener is experiencing at the time, as well as situational factors connected to the scenario concerned.

It is important to consider potential disparities between the perceptual outlook of people associated with the design of packaging closures and that of consumers who will actually open the packaging, since it is precisely such disparities that might lead to a closure design which thrills and delights the engineers and designers of a packaging manufacturing company, but fails to find favour with the general public who must open and use the packaging again and again. It is probably true to say that the majority of engineers and designers still fit the stereotypical mould of able-bodied, right-handed, males, with good grip strength and high visual acuity, and it is clear that they do not perceive the packaging in the same way as consumers using the packaging. Further, it is an inevitable consequence of such characteristics that one will not be able to foresee the difficulties others will have, or at least envisage them strongly enough to create designs that are easily opened by the majority of consumers, who may open as many as 50 odd different types of domestic packaging during a single day.

2.5.2 Perceptual affordances

The term *affordance* was initially used by Gibson (1977, 1979), a cognitive psychologist, in his attempts to explain how human beings perceived the world around them. Prior to Gibson, the majority of theorists assumed that people made sense of the world around them as a secondary phase within the process of perception itself. However, Gibson postulated that animals did not subscribe to this two-stage process of perception in making sense of their world (in other words, by taking an initial photograph of the environment around them, which was then examined and interpreted, as a secondary process, for example, both for opportunities and threats). Instead, Gibson asserted that perception allowed the direct and immediate evaluation of the potential uses (or affordances) of any object in the environment around them.

Affordances, in Gibson's terms, could thus be defined as the cues (or clues) that animals use to make sense of the world around them. Gibson's view was that the perceptual cues provided by affordances were absolute; they were a property of the environment that had consequences for the human being (or other type of animal) perceiving them. In Gibson's words (1991) "an important factor about the affordances of the environment is that they are in a sense objective, real and physical, unlike values and meanings, which are often supposed to be subjective, phenomenal, and mental. But actually, an affordance is neither an objective property nor a subjective property; or it is both if you like. An affordance cuts across the dichotomy of subjective–objective and helps us to understand its inadequacy. It is equally a factor of the environment and a factor of behaviour. It is both physical and psychical, yet neither. An affordance points both ways to the environment and to the observer."

Donald Norman, a psychologist active in the field of ergonomics and design, extended and refined the term, emphasising the importance of the interaction between both environment and perceiver. Affordances, Norman postulated (1988a, 1988b), were inherently interactive and were interpreted at a subconscious level. They represented clues to the function of an object – these clues, or subconscious suggestions, were described as 'a key to usability' as Norman (1988b) went on to explain "physical objects have affordances, a powerful, but little understood part of infrastructure. Physical objects can play a variety of roles. A rock can be moved, rolled, kicked, thrown and sat upon – not all rocks, just those that are the right size for rolling, kicking, throwing or sitting upon. The set of possible actions is called the affordance of the object. An affordance is not a property, it is a relationship that holds between the object and the organism that is acting on the object" and that "affordances provide strong clues to the operation of things." Plates are for pushing, knobs are for turning, slots are for inserting things into and balls are for throwing or bouncing. When affordances are taken advantage of, the user knows what to do just by looking: no pictures, labels, or instruction is required. Complex things may require explanations, but simple things should not. When simple things need pictures, labels, or instructions, the design has failed.

2.5.3 Affordances and packaging

Consumers therefore need to be able to pick up a packaged product and open it without having to think about how to open it or even where to start opening it. This is the real test of openability. Manufacturers of packaging need to ensure that their designs utilise perceptual cues (or *affordances*) that humans instinctively use to navigate their way around their environment. What are these affordances? What do they look like? Affordances are apparent in a myriad of forms: shapes, textures, patterns, the materials themselves, colours, symbols – and both our learned and innate reaction to these dimensions – all contribute to the affordances offered by a product's packaging. The affordances indicate to us, on a subconscious level, properties and functions that may not be obviously stated (indeed, properties and functions that may, in some cases, contradict explicit instructions or information given) but which are there to be perceived at a very immediate and subconscious level.

Of course, these contentions imply that when one picks up a packaged item in order to open it, the same object may offer different affordances (in this case, cues as to how it might be opened) to different people. However, knowledge of human perceptual processes, capabilities and limitations and even, for example, experience of social processes may be used to predict the most likely interpretation of the opening affordances for a target group of consumers. However, there is a lot of variability in the efficacy of these affordances. 'Easy-to-open' packaging typically presents effective affordances; several cues or 'clues' that the consumer will typically process on a subconscious level are used to propel the consumer into opening the packaging in an appropriate manner. The consumers are then free to use their attention on enjoying the product. Positive affordances allow the consumer to be led subconsciously to the correct conclusions in terms of quickly, easily and (hopefully) safely opening the products.

2.5.3.1 Strong and weak affordances

Affordances may be seen as ranging in strength from *weak* to *strong*, with *strong* affordances defined as where the subconscious clues are so evident that they are instantaneously translated to almost all human perceivers of the object, without the necessity for any cognitive resources to be redirected towards trying to make sense of the message that the affordances are trying to give out. An analogy for estimating the relative effect of the strength of an object's affordances might be that of a jigsaw puzzle: when affordances are *strong*, the entire jigsaw puzzle has been completed and every piece is in place; any perceiver should instantly recognise the picture created by the jigsaw puzzle. However, when the affordances of an object are *weak*, the jigsaw puzzle may be thought of as only half finished; to the perceiver, there is a picture vaguely recognisable, but some effort and concentration on behalf of the observer is needed to realise fully what the half-completed image may represent.

Thus, by contrast, *weak* opening affordances will mean that consumers may be unsure how to open the packaging. Since consumers will spend only a short amount of time trying to open the packaging properly (unless the item is particularly expensive or is a gift they are opening in front of the presenter), they will frequently resort to a more drastic opening solution, which, in many opening scenarios, will involve the use of a sharp knife or scissors. In the case of chocolate wrappers, hurried and/or impatient opening may lead to a slight increase in the force used to pull apart the packaging, leading in some cases to the jettisoning of the packaging contents onto the floor. Not only is there an economic cost but, perhaps just as importantly to the consumer, there is the inconvenience of missing out on the chocolate (whether this was destined to be a treat or simply a snack). There is also the potential for embarrassment if the episode is witnessed – embarrassment caused both by an apparent display of ineptitude on the part of the consumer, as well as a residual sense of guilt or tension (exhibited by even the most apparently antisocial of individuals) as to what to do about the spoiled product now littering the floor. Humans unconsciously file such feelings of guilt and embarrassment away in their minds, with the result that there may be a slight tendency to avoid the offending product for a short period of time.

The embarrassment factor will be particularly significant for teenagers and even their peers, who may just be onlookers to the scenario, who might decide to avoid a product that has proved to be a source of humiliation for someone. Of course, this age group (teenagers) would not explicitly cite the product's problematic packaging as a reason for avoiding it. Instead, the product itself may acquire a reputation for being 'uncool' in a kind of unspoken teen-wide agreement that removes the need to admit the real reason for avoiding this type of packaging.

2.5.3.2 True and false affordances

Affordances may also be defined as *true* or *false*, with *true* affordances meaning that the clues given by the packaging texture, shape, material, etc., will, if followed, allow the packaging to be opened quickly, correctly and easily. Alternatively, difficult-to-open packaging may have *false* affordances; that is, the clues provided actively mislead the majority of consumers into attempting to open the packaging in the wrong way. Consumers are likely to become particularly annoyed by this type of packaging (and with the brand owner or retailer championing it). Examples of products that fall into this category are a range of fresh dips in plastic tubs that are provided by one of the UK's leading retailers. Once consumers have learned to ignore the false affordances, opening the dips is no problem. However, the opening action cannot be carried out on auto-pilot and the consumer needs to concentrate on what they are doing. Affordances need to be robust for the consumer to be able to open the packaging on cognitive auto-pilot.

Weak or false affordances are frequently the main offenders in a bad design. If consumers cannot work out how to open packaging or use a product, it should be regarded as having a defective design. However, bad design can also include packaging that incorporates true and strong affordances, but are beyond most consumers' capabilities to open – for example, the caps of two-litre plastic bottles that contain carbonated drinks. It is easy to understand how one should open them, but the physical act of doing so is often extremely difficult.

2.5.3.3 Sources of variability in the perception of affordances

As affordances are intertwined with human perception, it is important to consider the different factors that determine how an individual might perceive them. Part of our perception (the interpretation of sensory information) is dependent upon previous personal experiences, and as such will depend on the person's background. Since affordances are relational, different people will perceive them in different ways. For example, the body size and strength of individuals may alter their perception of affordances, as will their goal in a particular situation (Chow, 1989). National and cultural differences may be evident in people's interpretation of affordances, and designers should be encouraged to follow the mantra of 'think global, act local' in designing their packaging, at least in terms of their target population. Other individual differences, such as gender or people's goals at any given time, will also affect the affordances they perceive on an object.

Packaging that has been designed well will display strong and true affordances; thus, consumers will instinctively and intuitively know how to open the packaging, and will be able to do so, without having to read any instructions.

2.5.4 Attention and information processing

Given what seems, at times, to be an overwhelming amount of data that are thrown at us every minute of the day – from each of our sensory systems that is actively gathering information all the time, from the television, radio, other people's conversations, the sound of vehicles, computers etc – it is not surprising that one of the most researched areas of cognitive psychology is the limits of our cognitive resources, and how our brains decide to process some signals and ignore others – the field of attention and information processing.

Humans possess only limited cognitive resources and thus have a finite attentional capacity. This capacity must be allocated between a variety of tasks, some of which will require more cognitive resources than others, depending upon factors such as the inherent level of difficulty; a person's own level of skill, experience and familiarity at performing each particular task (Hampson and Morris, 1996); the individual's psychometric profile; the individual's evaluation of requisite attentional demands for the task in hand (and its priority), and we must deduct the loss of cognitive resources through unexpected personal, social or situational distractions, to determine the allocation of cognitive resources between tasks at any given moment. However, our attentional capacity is not simply a function of the cognitive workload that we are able to deal with – it also depends upon the automaticity of the processes operating.

2.5.4.1 Controlled versus automatic processing

Cognitive psychology differentiates between *controlled* cognitive processes, which are carried out consciously and intentionally, and *automatic* cognitive processes, which are not under conscious control.

2.5.4.2 Controlled processing

Controlled processes require conscious attention and therefore incur a greater burden on our cognitive resources, eating into our attentional capacity and thus reducing the number of things we can do at a given time. In general, the more things we try to do, the slower we will be at each, although this will also depend on the difficulty level and importance of each task. However, controlled processing is extremely flexible, allowing us to adapt to a situation as it emerges and react to any novel stimuli as they occur.

2.5.4.3 Automatic processing

Schneider and Shiffrin (1977) describe automatic processing as "*not capacity limited, not affected by the limitations of short-term or working memory, and not dependent upon attention.*" Unlike its controlled counterpart, automatic processing is not subject to processing limitations, and does not place the same demands upon our cognitive resources. It can therefore be an advantageous method of preserving precious attentional capacity. Automatic processing occurs when we perform actions that are either very simple, or (to us) so well practised that we can, in effect, 'switch off' while doing them. It is a tribute to the cognitive make-up of human beings that almost any skill can become automatic as a result of frequent practice and that the skill may become so crystallised in our cognition that, once learned to such a degree that it has become automatic, we may be able to perform the same task (for example, riding a bicycle) years later without having to concentrate (i.e. using controlled processing) to do so.

The act of opening packaging is, in terms of our cognitive abilities, a simple problem-solving task, and, as we stand in our kitchens opening the packaging, we are generally using only automatic cognitive processes to guide what we are doing. In fact, we perform many of our routine daily tasks on this 'auto-pilot' setting, investing only a minimal amount of mental effort in performing the task. This leaves the balance of our cognitive resources free to coordinate one or more other activities, such as talking or actively listening to the radio. Many of the actions we perform every day do not require conscious controlled cognition – even driving, which involves the constant monitoring of information from a variety of sources, is often carried out without the need to draw on controlled and conscious cognitive processes.

For all its advantages in terms of freeing up cognitive resources, automatic processing does have a number of disadvantages. For example, automatic processing lacks the flexibility offered by conscious control, meaning that when presented with a task that appears to be either familiar and/or simple, we will immediately, and without even knowing that we are doing it, switch to automatic processing and perform the task using minimal cognitive effort. Once activated, automatic processing continues to govern our performance at a given task until the task is completed; thus, we may fail to take in new information and miss out because of this, or the occurrence of unfamiliar stimuli midway in a task may result in errors (Groome, 1999). One such example is when consumers wander the aisles of a supermarket during their weekly shop. Since this is quite a boring, yet familiar and practised task (at least, for many female shoppers), the automaticity of processing means that when searching for a specific product, such as coffee, they will function on auto-pilot to scan shelves stacked with numerous versions of brands of coffee for a particular pattern of packaging (for example, their preferred brand). If the product is not in its usual place, or there has been a change in the appearance or shape of the packaging, the automatic processing may fail to pick out the changed brand, and the consumer may conclude that the shop has run out of stock and move on to the next item on their list, *sans* coffee. It is only when/if the shopper deliberately changes to controlled processing, and actively attends to, and searches, the various items on the shelves (an act that will take significantly more time, particularly if this happens for a number of products) that the preferred product may be located.

In terms of opening packaging, there are further problems with automatic processing: the reading of short phrases, or the interpretation of signs and symbols, is generally carried out at an automated level of processing – indeed, it is so automated that it is virtually impossible for most people to look at a short phrase and NOT read it. For example . . . do not look at the following phrase in the text box:

DO NOT READ THIS!

Too late! The interested reader is directed to studies on the Stroop Effect developed by Flowers et al. (1979) for further information on this phenomenon.

One of the problems of reading on auto-pilot, however, is that we may not process all the information. For example, at an automated level of processing, we will often fail to process negatives. Therefore, packaging, such as cartons, that display opening instructions with the phrase DO NOT OPEN THIS END on one side (and blank on the other) will frequently result in the consumers opening the carton *at the wrong end*. The consumer has automatically processed the phrase DO NOT OPEN THIS END (which has thus become DO OPEN THIS END) and accordingly starts to open the packaging on that (the wrong) end.

Behaviour may often be based on automatic processing of information, particularly with actions such as opening the packaging, which are carried out with high frequency and, other than on occasions such as birthdays and Yule, little focus or concentration. Although automatic processing has evolved to free up our cognitive workload, the very nature of the shortcuts that define it may also interfere with our performance on a task and increase the susceptibility to errors, when circumstances are not identical to those that we are accustomed to.

2.5.5 Human errors

Errors in human behaviour can be sub-divided into two main categories: slips and mistakes – the difference being that mistakes are carried out deliberately, generally from a misguided belief that what the person is doing is correct (for example, wrongly believing that a picture on the label of a new jumper means that the garment should not be machine washed, and so doing, when, in fact, the symbol actually means the opposite). The person machine washing this item of clothing would thus have made a *mistake*. In contrast, slips result from automatic (or automated) behaviour, when the goal of the individual is correct, but there is an error in the carrying out of the actions required to attain the goal. In the previous example, this would mean that the consumer understood that the picture on the label meant that the garment should NOT be machine washed, but since almost 98% of the household laundry is done in the washing machine, he/she 'accidentally' placed the garment into the washing machine anyway.

The study of slips in everyday life was instigated by Sigmund Freud, an (in)famous psychoanalyst, who termed it 'the psychopathology of everyday life'. The interested reader may wish to obtain a copy of Freud (1901) *The Psychopathology of Everyday Life*; the book is available in many versions, in almost every language. However, few of the slips that people make in their everyday lives may be deemed truly 'Freudian' in the darker sense of the word. However, slips result from our automatic performance of low-level behaviours and are generally simply the result of a lack of attention on behalf of the performer. Slips occur more frequently in skilled behaviours or those that we practise or repeat on a regular basis (and therefore carry out in automatic mode). People rarely make slips when they are learning a new skill, since they will be diverting more of their cognitive resources into focusing on the task at hand and using controlled processing.

Applied to consumer behaviour, it could be hypothesised that cognitive constraints may lead to errors when opening a package. This could occur in two ways – firstly, the consumer may become so used to performing certain actions when opening a package that they may utilise automatic processing and consequently experience error through lack of controlled processing of information relating to the task. Secondly, most packaging is opened while the consumer is concentrating on a number of other tasks, such as listening to the radio. Distraction at the time of opening packaging may lead to accidents or errors. The nature of the packaging design may also, as mentioned previously, lend itself to errors.

In terms of packaging closures, designers should spend time simulating any probable or possible slips that may arise as a consequence of attempting to open packaging, and should seek to modify the designs to reduce or eliminate the occurrence of such slips.

2.6 Individual differences

2.6.1 Decision making

In terms of individual differences and the way people approach the opening of packaging, particularly problematic packaging, it is useful to consider the psychology of decision making. Decision making is concerned with choices, and how – or by what processes – people choose one option over others. The relevance of decision making with respect to packaging is apparent in two main ways: the influence of any problems opening packaging on future purchasing decisions, as well as affecting the methods (and degree of, for example, perseverance) that an individual might engage in when attempting to open packaging.

2.6.1.1 Effect on re-purchasing decisions

Decision-making scenarios can be classified into three main types: (i) certainty, (ii) risk and (iii) uncertainty (Busemeyer, 1985). A decision made in certainty involves a decision with a known outcome; a decision made in a risky scenario may result in a variety of outcomes, but importantly the outcomes (and associated probabilities of them occurring) are explicitly known; whilst a decision made in the third type of scenario – uncertainty – could result in a number of different outcomes, not all of which are explicitly recognised by the actor involved. Sitkin and Weingart (1995) proposed that an individual's decisions could be explained in terms of a number of key dimensions, including outcome history (the outcome of any previous risks taken); risk propensity (an individual's current tendency to take risks); and risk perception (an assessment of the hazards in any given situation). Thus, in terms of packaging, consumers are affected by the success or otherwise of their previous purchasing decisions and will take into account the risks (whether financial and/or social of not being able to open packaging) before buying what may be deemed a 'risky' product again.

2.6.1.2 If it's the last thing I do . . . risky decision making

The manufacturers and retailers of packaging frequently appear to underestimate the lengths that consumers will go to when trying to open packaging. Possibly there is ignorance concerning the problems presented by the packaging, a lack of research focusing on realistic opening scenarios (with real consumers) and/or a naive belief that if the packaging closure proves too troublesome, the consumer will return it to the shop and not continue to try to open it regardless. The extent to which people will persevere with attempting to open packaging is reflected in their decision-making style, and this is, in turn, affected by the particular scenario they find themselves in.

In a research study (see, for example, Winder et al., 2002; Winder, 2003) that we carried out in-store at a major supermarket chain across four locations in the United Kingdom, the resulting data demonstrated that over two-thirds of the consumers studied displayed the personality trait of social resistance (that is, the extent to which they are disinclined to ask others for help or advice, as reported by French et al. (1993)). Since this survey was, by necessity, biased towards the older, female consumer, it is certain that males and younger consumers would be even more likely to show high levels of social resistance as a general personality characteristic. Our research demonstrated a significant positive relationship between the decision-making style of social resistance (disinclination to ask for help) and the seriousness of the injury individuals had incurred when attempting to open packaging.

2.6.2 Personality and mood

Personality can be described in terms of an individual's style of thought, emotion and behaviour and the psychological mechanisms behind each of these factors. Personality reflects consistency in the style in which we think, act and feel as we respond to the world (for example, objects, situations and people) around us. The trait approach to individual psychometric differences supports the observance of an individual's behaviour upon the effect of internalised personality characteristics (Funder, 1997). These characteristics are hypothesised to affect all aspects of behaviour and to control an individual's actions independently of circumstance (Costa and McCrae, 1988). As such, the effect of personality upon consumer behaviour should be taken into account when designing packaging closures for a specific target consumer group. In addition, designers need to understand the relative mood states that are likely to be present in consumers opening and using their packaging. Mood states are generated from within an individual, but unlike personality traits, mood states are fluid and transitional. Thus, designers and manufacturers should consider who are most likely to buy their product, the type of mood the consumers might be in (or might visualise themselves in) when opening the packaging and the context or scenario in which the packaging might be opened. All these factors will affect openability. For example, let us consider the personality trait of neuroticism, which has been found to correlate positively with age and being female.

2.6.2.1 The neurotic consumer

As a personality trait, the neurotic individual will display a high level of residual anxiety and will seek to actively avoid potentially negative stimuli or outcomes

(Necka and Szymura, 2001). This trait has been found to both predict the number and level of reported difficulties opening packaging (Winder et al., 2002) and also produce ‘safe choice’ buying behaviour (Horton, 1979). Interestingly, our research indicated that neuroticism was predictive of *complaints* about packaging, but not of actual *injuries*. Of course, there are situations in which we will all display high levels of neuroticism (for example, when dealing with expensive products or ones that are difficult to replace). Some of the correlates with the trait of neuroticism are age (older), sex (female) and anxiety levels (of a generally anxious or nervous disposition), and manufacturers of products that are aimed specifically at these consumers should think through (and test) their products very carefully before unleashing them on their customers. Of course, the readiness of these customers to articulate and report problems with a product and its packaging can be harnessed as a powerful ally, if acted upon, in ensuring that the final packaging and product design is well received. The point about neurotic consumers is simply that they will articulate problems that other consumers have only subconsciously picked up upon. A subconscious message can be a more powerful master than a conscious one, as the consumer may not explicitly realise why they do not really fancy buying a certain product again!

2.6.2.2 Extroverted, impulsive and time-hungry consumers

Extroverts have been shown as more likely to rate ‘hurry’ as a reason for difficulties experienced opening packaging (Nelson, 2004). This may partly be explained by the clustering of characteristics such as high activity and sensation-seeking behaviour with extroverts (Lucas et al., 2000). Similarly, the higher the persons’ scores on impulsivity as a personality characteristic, the less likely they are to report reading instructions and the more likely they are to report difficulties opening packaging (Nelson, 2004). These findings are intuitively valid and agree with previous research that indicated that impulsivity has an effect upon error rates (Dickman, 1990).

Again, there are situations (or types of products) for which we will *all* display high levels of extroversion or impulsivity, and products designed specifically for these types of occasions (for example, gifting) should take into account the speed and lack of care that will be exercised by even the most cautious consumer when opening packaging under such circumstances. Packaging closures that are likely to be opened when the consumer is in a hurry (either because they are excited and want to access the contents of the packaging quickly OR because they need to get to the contents inside urgently, such as with medicines) should take into account the likely speed of opening of the packaging, and the fact that consumers are unlikely to read opening instructions while in a hurry.

The study of individual differences can thus be used to highlight aspects of packaging-related behaviours that may be present in some consumers *all* of the time, but that nevertheless are present in all people *some* of the time, depending on the product or the opening scenario.

2.7 Packaging-related constraints and issues

2.7.1 Packaging materials

The materials from which packaging is constructed, and the relative qualities thereof, will also affect the types of accidents and injuries that are likely to occur with packaging. Three main types of materials are responsible for a large proportion of the packaging accidents and injuries reported in hospitals: metal, glass and plastic.

2.7.1.1 Metal

Metal (in the form of food and drink cans, usually made of aluminium or steel, and available in three main formats: traditional cans, ring pulls (of which there are now several designs) and key operated) is reported to account for 41.97% (28 075) of the reported domestic packaging accidents. Approximately one-third of these (note: these figures are from the last recorded DTI survey back in 1997; I would expect the number of accidents with metal packaging to have decreased significantly with the phasing out of the trapezoid corned beef tin) were reported as involving traditional trapezoid corned beef tins with a key, which, on opening, left a sharp jagged edge. Combine this with the target consumer for this product – the elderly, who, at this present time, represent a generation accustomed to rations and espousing waste of any type. Add in decreased physical strength and dexterity, and it is evident why the number of accidents is so high. The trapezoid corned beef tin has now all but been replaced by manufacturers aware of the dangers inherent in the design and anxious to reduce accident rates. In terms of metal as a packaging material generally, a high proportion of the injuries are reported as being cuts from the edges of tins while they are being opened or disposed of.

2.7.1.2 Glass

Glass (in the form of bottles, jars and canisters) is reported to account for approximately 29.53% (19 752) of all food and drink packaging related accidents (note that this figure, as with the metal and plastic sections, does not include accidents with medicine packaging). The majority of the injuries are sustained while disposing of broken glass, with the latter occurring potentially as a result of the containers being heavy and/or slippery; this may occur if the container is still slightly damp immediately after being removed from the fridge. A second problem reported involving glass packaging occurs during initial opening, and is related to *torque*, or the strength required for opening the packaging.

2.7.1.3 Plastic

Plastic (in the form of bottles and spray bottles) is reported to account for 14.17% (9480) of food and drink packaging related accidents, as well as the majority of medical packaging accidents. Of the reported accidents with medical packaging, 90% are poisonings, often occurring when the packaging is re-opened and used successively after the first opening of the product. Children may have access to the improperly closed packaging containing corrosive substances such as bleach, or packaging containing medicines, despite legislation requiring the use of CRCs, which was designed to prevent such accidents. The poisoning accidents cited above occur for three main reasons: the CRC has failed and a child has accidentally accessed the contents of the container; the CRC was not engaged properly in error by the adult consumer; or the CRC was deliberately not engaged (or, for example, the contents were transferred to a different container that did not have a CRC) possibly due to difficulties with opening or using the child-resistant packaging.

The majority of the remaining accidents with plastic packaging occur through inappropriate tool use. Typical accident scenarios include incidents where consumers have reported openability problems with flexible packaging (such as for cheese products), and a tool, generally a sharp knife, is used to open the packaging. It should also be noted that the type of hard plastic packaging that is used to package products such as toys and hardware items (see Fig. 2.2) was particularly highlighted in our research as causing the consumers great difficulties.

Figure 2.2 An example of hard plastic packaging that consumers find extremely difficult to open.

This type of hard plastic packaging is particularly hazardous, since consumers will quickly move on to using knives or other sharp objects in their efforts to open the packaging. Typical attempts at opening consist of the consumer trying to 'puncture' the plastic by jabbing the sharp knife or screwdriver into the plastic. Since the plastic surface is also quite slippery, this can result in quite nasty injuries to the hands, arms and even legs of the impatient and/or frustrated consumer.

2.7.1.4 Other packaging materials

Foil and film are reported to account for 1.94% (1299), aerosols for 1.34% (893) and an unspecified 'other', which presumably comprises packaging containing a mixture of materials, for 11.01% or 7390 (note that due to the rounding of numbers, these percentages sum to 99.96%) of food and drink packaging related accidents.

Of course, readers should note that the above data are becoming rather outdated, given the (now) fast-moving world of the packaging industry, and the DTI should, for the sake of consumers and the packaging industry alike, prioritise a further data collection exercise with regard to packaging accidents and injuries.

2.7.2 Opening instructions

The fact that openability (and usability) is a major area of concern to consumers will be nothing new to the people reading this. Many people in the industry may have become very frustrated at the consumers' apparent apathy in even using the help they are given to open packaging – the opening instructions. While a failure to include any opening instructions at all on packaging might be noted and heavily criticised by eagle-eyed consumers, the reality is that very few consumers ever bother reading opening instructions, as the results of our studies outline. From one study of over 250 consumers, only 18% of subjects reported 'always' reading the instructions when faced with an *unfamiliar* packaging design. The majority (56%) of consumers were happy to admit that 'they couldn't be bothered' to read opening instructions and would simply struggle on trying to open the packaging, using progressively more dangerous implements/opening methods. The people most likely to read opening instructions were the elderly and those people who lived alone. However, with over 34% of *all* our respondents (not just the elderly ones) reporting that the opening instructions on packaging were generally written 'too small to read', consumers who do decide to seek help by making the special effort of reading the instructions may be left feeling frustrated at the perceived lack of thought by the product brand owners. Our research indicated that, understandably, consumers were more likely to read opening instructions if the package contained an expensive product, and that they were significantly less likely to read instructions when they were in a hurry (typical 'hurry' scenarios included being in the middle of a recipe, rather than life-threatening incidents, however).

With regard to warning instructions and opening instructions, mere compliance with government regulations and trade standards is not enough; the packaging industry needs to accept that people rarely read opening instructions and ensure that the design of the packaging is intuitively accessible to consumers (as well as providing written guidelines for those who do take the time to read it).

2.7.3 Use of tools

Although some of the most severe packaging accidents involve a tool, such as a knife, few of these accidents reflect appropriate opening strategies, as recommended by the packaging manufacturers. Thus, we need to make a distinction between the kind of tools that might aid opening packaging, and balance this with the kind of tools that consumers will resort to when actually opening the packaging. Bearing in mind that consumers will often try to struggle for a few minutes with a package, and that the tool they will therefore resort to would be the one that is (i) convenient to hand and (ii) certain to do the job, it is incumbent upon designers to take into account potential tool use (however dangerous or ill advised) when designing their packaging.

2.8 Conclusion

2.8.1 The consumer's perspective

Manufacturer and retailers frequently report ambiguous findings when asking consumers directly, and our study (see Winder, 2003, for full methodology and results of this study) adopted a systematic approach to analysing the key factors for consumers with regard to the design of packaging. Advanced statistical analyses were performed on the resulting data, allowing us to distil all the information obtained on a range of attitudes about diverse aspects of packaging to its significant core. The results indicated that consumer attitudes to the key functions of packaging could be reduced to three main areas of focus (presented in order of statistically measured importance): (i) openability (and usability) of packaging; (ii) aesthetically pleasing packaging; and (iii) concerns over the excessive use of packaging materials.

The third factor, concerns over the excessive use of packaging, revealed several different rationales as to why companies should endeavour to refrain from the use of excessive packaging: the perceived harm done to the environment (and consequently also to the retailer's/brand owner's image as not caring about the environment – and therefore, to take it one step further, as a greedy company that did not care about the consumer either); the financial cost (to the consumer) of excessive packaging; and finally the additional problems of transporting and storing the product due to the extra weight, height and/or bulk, which was a direct result of the extra packaging.

2.8.2 Problematic packaging

The data reported in this section were collated through a combination of diary studies, interviews and questionnaires by the Packaging Research Group between 2000 and 2004, and were designed to highlight, in very simple terms, the key packaging closures that the consumers find most difficult to open. It is hoped that manufacturers of packaging will be able to utilise this information to capitalise on their successes and to improve their failures, as judged by consumers. The generic categories used were *beverages*, *food products*, *health and beauty products* and *household, garage and garden products*, and the top three most difficult types of packaging are listed below for each category.

Beverages: (1) cartons; (2) plastic bottles; (3) glass bottles.
Food packaging: (1) cans/tins with ring pulls; (2) sealed plastic packaging (such as that found on cheese products); (3) glass jars (for example, jam jars).
Health and beauty products: (1) plastic bottles; (2) containers with CRCs; (3) shrink wrapped items.
House, garage and garden products: (1) plastic bottles; (2) bottles with a CRC; (3) shrink wrapped items.

It should be remembered that the above categories may be influenced by other factors, such as the frequency of opening the problematic packaging, and do not necessarily represent an absolute scale of difficulty.

2.8.3 Problems assessing the openability of packaging closures

The problem that companies have with trying to measure packaging openability is exactly the same as that encountered by psychologists in many of their experiments. People's behaviour in an artificial setting can be very different to their behaviour in real life. In terms of packaging, the best test for assessing openability is not with a focus group, or even by giving the consumer some samples 'to open in their own time' at home. In the former case, there will be group effects (including the emergence of a majority consensus) that will bias the results, and in the latter instance, the participants will invariably switch to controlled conscious processing when they are opening the 'test' packaging, because they know that it is important for them to be able to recall (perhaps they have been asked to write down) their opinion of the packaging and its openability.

2.8.3.1 How can we help designers?

Given the numerous studies we have conducted, it was deemed useful to develop criteria for the design of packaging closures, and the following are adapted from the work of Kellaher (2003), Nelson (2004), Winder (2002a, 2002b, 2003) and other studies by Winder and Lundstrom carried out at the Packaging Research Group.

- The designer should have a logical and practical opening method in mind when designing the packaging.
- The opening scenario should not stop at the point when the packaging is opened, but should encompass the use of the product, the (frequent, if appropriate) re-use of the product and the disposal of the packaging.
- Affordances should, where possible, be consistent for similar packaging types.

- Affordances designed to aid openability should be distinct from affordances of other packaging functions.
- If unfamiliar or novel, the affordances of openability should be stronger than the affordances used conventionally.
- Designers should not rely on familiarity; affordances of openability should be accessible to first-time users.
- Designers should spend time generating any probable or possible slips that may arise from their packaging, and should seek to modify the designs to reduce or eliminate the occurrence of such slips.
- Designers should consider the likely speed of opening the packaging, within the design process (taking into account factors such as likely opening scenario, type of product and target consumer).

Finally, it was my intention in this chapter to take the reader on a journey through the psychology of packaging; I hope that this journey has proved to be both interesting and informative. Of course, the overriding aim of this chapter was not merely to stimulate readers' interest, but, taken as a whole, to be seen as a promulgation of the work that still needs to be done in this area, together with providing an account of the difficulties that the packaging industry faces, not least apropos consumers themselves, as it strives to improve the design of packaging closures.

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3 Closures for metal containers

Bev Page

3.1 Introduction

It is estimated that the total world market for metal containers is in the order of 410 billion containers per annum. This comprises 320 billion drink cans, many of which are for processed drinks such as tea or coffee; 75 billion processed food cans; 10 billion aerosol cans; and 5 billion general line (GL) cans. This last group includes containers of many different shapes and sizes for dry foods, edible oils, inks, coatings, lubricants, other industrial products, personal care and car care products, in addition to those used for promotional and decorative products.

The standards required of metal containers may be divided into two groups: performance and non-performance. All containers used for holding wet food, drinks, paints, inks, solvents and other industrial products, as well as aerosols, are considered to be performance containers because they are essentially precision containers. They must be pressure or liquid tight, and capable of preserving the contained product under severe conditions. Non-performance containers do not have to be liquid tight and may therefore be made with less precision. Clearly, the methods used for closing and sealing these two classes of containers will greatly differ.

The closing and sealing systems used for wet food and drink products provide long-term ambient storage of perishable products. In order to achieve this, the closure, together with the body of the container, must withstand any heat processing required to sterilise or pasteurise the product. Additionally, for processed food cans, the seal must also prevent the passage of microorganisms into the container, whilst for drink cans and aerosols it must also prevent the loss of internal pressure to the atmosphere. Thus, closed metal containers, as complete package systems, have the following functions to perform:

- Preserve and protect the contained product
- Resist the chemical actions of the contained product
- Withstand the handling and processing conditions
- Withstand the external environmental conditions
- Have the correct dimensions and the ability to be practically interchangeable with similar products from other supply sources (when necessary)
- Have the required shelf display properties at the point of sale
- Provide easy opening and simple/safe product removal
- Be constructed from fully recyclable raw materials

The closure system must also satisfy all these requirements, in addition to being able to provide an appropriate method of sealing the open end of the container for the particular product packed, and the pack performance; it must be capable of being opened by hand, by use of a separate tool or by the operation of an attached key. In many cases, where consumers are unlikely to consume the entire product immediately, the system should also, where appropriate, provide a re-closing facility: for some products, a slip lid or plastic dust cover may provide sufficient protection. However, for many products, it is necessary to provide a closure that can be re-sealed to prevent the deterioration of the product or to facilitate safe transport or aesthetically acceptable storage of the partially filled container.

Aperture sizes vary immensely across the range of metal packages. For liquids, whether as drinks or hazardous chemicals, the aperture will normally be small to reduce the risk of spillage. In many designs, the shape of the container body is used to assist in completely draining the can. In other examples, pouring systems are attached to the closure to facilitate the safe and efficient dispensing of the product. For solid or semisolid food products, the aperture, which may be a full-aperture easy-open end, must be sufficient in size to remove the contents without damaging the product. At the other end of the range, tapered pails for industrial products, after removal of the closure, provide an aperture which is equal in size to the full diameter of the container body. This allows a dispensing pump assembly to be lowered directly onto the top surface of the product, or a brush to be loaded with paint, or the container to be thoroughly cleaned out before being sent for recycling. The re-sealable bottle-shaped drink can introduced in Japan in 2002 is an example of how the metal packaging industry recognises the need for added convenience to be provided, where this is technically feasible.

Closures, such as mechanically seamed ends on processed food cans, contain a centre panel area, which must flex to accommodate pressure changes within the container during heat processing. This puts additional requirements on the design of the closures. The external decoration of a closure often forms part of the overall decoration of the container. In these cases, it may contain all or part of the container identification label, in addition to being colour coded to match the body. Where filled containers are viewed from above by the ultimate purchaser, the visual impact of the closure decoration or design can be an important selling aid.

For the high-volume commodity market products, such as processed food and drink cans, it is quite common for the company filling the cans to purchase the can bodies and closures from more than one supplier. This implies that, in addition to closures (ends) from supplier A being fitted to his own can bodies, for much of the time these same ends are also being fitted to can bodies from supplier B, and vice versa. This requires a high degree of interchangeability between competitors' products, if filling line efficiency is not to be compromised and adequate product shelf life is to be maintained. In practice, this can be achieved only if sufficiently stringent industry seaming standards are used as the basis for component manufacture and filler seaming operation and control.

Certainly, it is true to say that most, if not all, performance metal containers are manufactured to nationally or internationally accepted standards of construction and performance. Containers for the transport of dangerous goods (flammable, toxic or corrosive products) or marine pollutants have their performance regulated by the United Nations Recommendations on the Transport of Dangerous Goods. For these items, specific certification and test procedures are mandatory.

3.2 Materials and methods used for construction of metal containers and closures

3.2.1 Materials used for metal containers and closures

Both steel and aluminium are used for metal container and closure construction. These are both relatively low-cost materials, which are non-toxic, have adequate strength and are capable of being work hardened.

3.2.1.1 Steel

Steel is used in the form of a low carbon steel as blackplate, tinplate or tin-free steel. Blackplate may be used without additional organic coatings for contact with non-corrosive products such as oils and waxes.

Tinplate is created by electrolytically coating blackplate with a thin layer of tin. The tin is coated on both sides of the plate in weight to suit the internally packed product and the external environment. Different weights may be applied to each side of the plate. Tin, plated in sufficient weight, provides good corrosion-resisting properties to steel and is suitable for direct contact with many industrial products and specific foodstuffs, such as white fruits and tomato-based products. However, for most foods and drinks, it is necessary to apply an organic coating to the inside surfaces of the tinplate container, in order to provide an inert barrier between the metal and the product packed. This barrier prevents chemical action between the product and container and also prevents taint or staining of the product by direct contact with the metal. The tin surface assists in providing good electrical current flow during welding processes and, being a very soft metal, it also acts as a solid lubricant when forming thin-wall two-piece cans by the wall-ironing process.

Tin-free steel, also referred to as electro chrome coated steel (ECCS), is created by electrolytically coating blackplate with a thin layer of chrome/chrome oxide, which must then be coated with an organic material to provide a complete corrosion-resistant surface. The metallic layer of tin-free steel provides an excellent solution for adhesion of liquid coatings or laminates to the surface and is marginally less expensive than tinplate. However, the matt finish does not provide a reflective surface like tinplate does after it is coated with clear lacquer. Tin-free steel, in its standard form, is not suitable for welding, without prior removal of the chrome/chrome oxide layer. Japanese steel makers have developed modified tin-free metallic coatings that do permit satisfactory welding of this material.

3.2.1.2 Aluminium

Aluminium for light metal packaging is used in a relatively pure form, with manganese and magnesium added to improve the strength properties. This material cannot be welded by can-making systems and can be used only for seamless (two-piece) containers. Because of the products normally packed into aluminium containers, the internal surfaces are always coated with an organic lacquer. There are certain conditions where coated aluminium easy-open ends mechanically seamed to coated steel container bodies, which are later subjected to full heat processing, may give rise to local bi-metal corrosion. This is discussed further in Section 3.3.2.

3.2.1.3 Coatings, inks and film laminates

Organic materials are used to provide barrier or decorative coatings to many types of metal containers and closures. These may be in the form of liquid-applied coatings and inks, film laminates or organic extrusion coatings. Details of the stage in the container construction process at which these are applied are described in the following sections.

3.2.2 Container and closure construction methods

There are two broad categories of cans by construction method: two-piece cans and three-piece cans. Two-piece cans, formed from flat sheet or heavy disc, are seamless, except for the point where the closure is fixed to the body (two pieces of metal to create the closed can). They may have circular or other shape of cross section.

Three-piece cans are made from a flat sheet of metal rolled into a cylinder (or other cross section) with a small overlap at the seam. The metal at this seam is joined by electric welding, soldering, nylon bonding or folding into a lock seam (with or without the addition of hot melt adhesive as a sealant). Closures are then fixed to both open ends of the body to form a closed container made from three-pieces of metal. Starting from these basic methods, can bodies are ultimately constructed in four different ways:

(i) *Two-piece cans formed from flat sheet* (*tinplate, tin-free steel or aluminium*) *for use as performance containers*

Single drawn or multiple drawn cans (draw–re-draw (DRD)) have wall thickness similar to that of the can base. These cans are generally used for but not restricted to designs where the can height is equal to, or less than, the diameter of the base. For these containers, the internal and external coatings/decoration, whether liquid or film laminate, are normally applied to the sheet metal prior to the forming processes.

Drawn and wall-ironed (DWI or D&I) cans have wall thickness significantly less than the can base. These are formed by a process that initially forms a drawn container as described above. Further forming by an ironing process reduces the wall thickness significantly whilst leaving the base thickness untouched. This system is used for ‘tall’ cans, where the height is greater than the diameter of the base. DWI cans cannot be made from tin-free steel, because the brittle surface is not suitable for the wall-ironing process. For these containers, the internal and external coatings/decoration are always applied in the liquid form and only after the basic body-forming operations have been completed. It is expected that newly developed extrusion-coated tin-free steel will be capable of being ironed in the future.

(ii) *Two-piece cans impact extruded from a circular slug of aluminium for use as performance containers*

Impact extrusion is used to form circular section cans where the height is significantly greater than the base diameter. Thick-wall cans made by this process are used for containing high internal pressure. Thin-wall containers of this type become flexible tubes for containing paste and viscous liquids. For these containers, the internal and external coatings/decoration are always applied in the liquid form and only after the basic body-forming operations have been completed.

(iii) *Three-piece cans formed from tinplate or blackplate sheet with the side seam welded, soldered or nylon bonded for use as performance containers*

Three-piece welded side seam cans are initially made with circular cross section. This shape may then be re-formed to other cross sections and may also be re-formed into a tapered body with different diameters at each end. Soldered and nylon-bonded side seam cans cannot be re-formed because the side seam has insufficient strength to withstand the re-forming operations. For these containers made from tinplate, the internal and external coatings/decoration (if required) are always applied to the sheet metal in liquid form prior to the body-forming process. Where special internal performance is required for certain soft drink cans, an additional layer of internal coating may be applied by spray after all the forming operations have been completed. For blackplate welded containers, such as tapered pails or drums, coating is done by spraying after the body-forming and base-fixing operations have been completed.

(iv) *Three-piece cans formed from tinplate with the side seam formed by a mechanical lock seam and suitable only for use as non-performance containers*

This method of side seaming normally produces a non-performance container. However, addition of a hot melt adhesive to one side of the joint prior to forming the seam will upgrade the component to a performance container.

Lock seam cans may be formed into containers of many different cross-section shapes. However, in this system, the final shape of the cross section is created by folding the metal into shape before the lock seam is made in the body. For these containers, the internal and external coatings/decoration are always applied to the sheet metal in liquid form, prior to the body-forming process.

3.2.2.1 Closures

Metal closures for metal containers are initially formed from pre-coated/pre-printed sheet as two-piece single drawn open-ended can bodies to which special features are added to allow them to function as closures. For performance containers, the basic method of can construction described above does not influence the design of closure with which it must be used.

Metal closures for glass and plastic bodies, described elsewhere in this book, are also formed in similar ways to those for metal containers. For example, rolled-on aluminium caps are initially formed as (deep) multiple drawn can bodies, prior to the addition of knurling, tamper-evident features and sealing wads or compound. Likewise, lug caps, screw caps and push–twist caps for glass jars are initially made as single drawn containers before the formation of lugs, threads, tamper-evident features and the addition of wads or sealant materials.

3.3 Closures for performance containers (heat processed or normally pressurised containers)

3.3.1 Introduction and overview of section

Performance containers, for products that are either heat processed in the container or include gas for pressurisation, such as carbon dioxide for carbonation, require closing and sealing systems of the highest possible integrity. These are normally satisfied either by mechanical (metal-to-metal) double seaming or by heat-sealing techniques. Mechanical double seams are also used for fixing the bases and top cones (where fitted) of aerosol containers. The valve of an aerosol is fitted to the body with a crimp seal system, which is described elsewhere in this book. The closures for cans that use double seam systems are normally described as can ends. Figure 3.1 shows typical cross sections of processed food and drink cans.

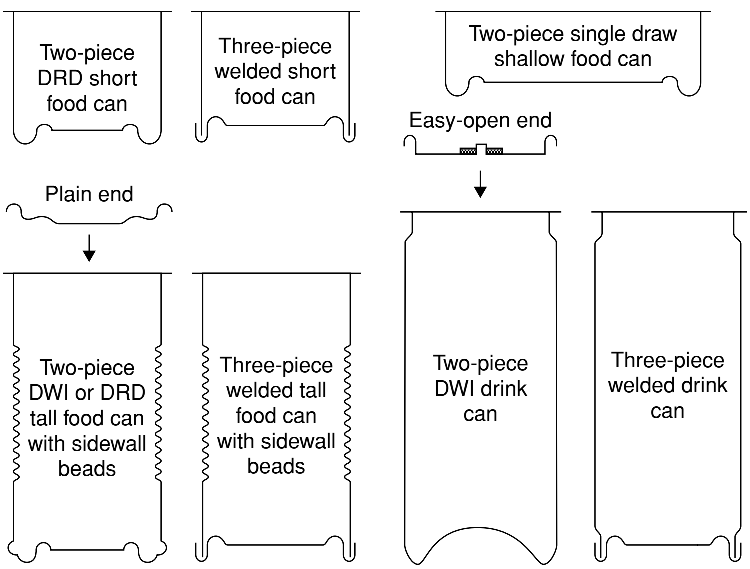


Figure 3.1 Processed food and drink can types. (Reproduced, with permission, from Page, B. (2001) *Metal Packaging: An Introduction*. Pira International.)

3.3.2 The effects of heat processing on container and closure

For the preservation of wet food products, where sterilisation has not already been done prior to filling as in aseptic processes, the can and its contents must be taken through a heat-processing cycle immediately after the filling and closing has been completed. This process is done to sterilise the contents and the surfaces of the can. For long-term storage at ambient conditions, this process is necessary to kill all living organisms inside the can. Currently, the majority of food cans are heat processed with steam after filling, and the rigorous processing conditions put significant physical demands on the container and its coatings. These conditions particularly affect the closure and the seal between the can and the end, and a brief description of the process cycle is given below.

3.3.2.1 Heat-processing cycle for metal cans

Depending on the type and nature of the product in the can, together with the can size and shape, typical processing temperatures may vary from 113 to 132°C, with processing times ranging from 5 minutes to periods in excess of 1 hour. The sterilisation (retorting) process is essentially the same as that of a pressure cooker, except that industrial retorts may work on continuous as well as batch systems. When the food product is filled into the can, it is usually warm to aid conveying. Immediately after the closure has been fitted, the pressure inside the can is either atmospheric or slightly below if the can is steam-flow-closed. As the can enters the continuous retort, or the batch retort is closed, full steam pressure acts on the outside of the can and the pressure imbalance acts to implode the can and end. As the product in the can reaches the same temperature as that of the heating steam, the total pressure inside the can becomes greater than that inside the retort. This is because the total in-can pressure is the sum of the thermal expansion from the increased partial pressure of the water in the product and that of the expanding headspace gases. At this point in the cycle, the pressure in the can is sufficient to deform the ends outwards. As the hot can exits the retort and passes through an external cooling process, the can and contents slowly cool down to ambient temperature and a negative pressure is induced in the can (because, when originally sealed, the contents were warm). The end on the can now returns to its original profile. In the process of steam flow closing, most of the air in the top of the open can is flushed out by a jet of steam immediately before the can end is seamed on. When the retorting process is used for heat-sealed containers in which the lid material is relatively weak, an over-pressure is applied to the retort to reduce the expansion within the container and prevent the closure being permanently damaged during the heating cycle.

Many drink products need to be pasteurised after filling. Typical processing conditions for a lager product would be 60–62°C for a period of 15–25 minutes. This contrasts with the conditions for orange juice, which are 85–93°C for only 30 seconds. The duration of the process and the temperatures achieved during the full heat-processing cycles for food products are sufficient to initiate local corrosion between certain dissimilar metals that may be in contact with each other in the container. Experience has shown that the coating materials normally used on steel food can bodies and aluminium ends are not sufficient to prevent this type of chemical action from taking place. For most food cans, therefore, it is expedient to use the same metal type for both body and end. In special situations, more robust coating systems are used to permit, for example, the use of aluminium easy-open ends on steel processed food cans. One system, albeit very costly, is to apply a coating of pure aluminium metal over that of the aluminium alloy used to make the end. This method, after addition of a suitable organic coating over the pure aluminium, has been shown to prevent bi-metal corrosion when the aluminium end is seamed to steel processed food cans.

3.3.3 Types of heat processed or pressurised cans on which double seams are used

Heat-processed cans, and those at pressure during normal service, have the highest integrity requirements of any metal containers produced. These may be either two-piece or three-piece (welded, soldered, nylon-bonded) performance containers. Typically, these cans will be for processed food, processed drinks, beer and carbonated soft drinks. For all these products, the complete metal package must be capable of safely preserving the contents at ambient conditions for at least 3 years. However, the local ambient conditions can vary from those in an aircraft at 10 000 metres altitude to those in a tropical rainstorm, and from those inside a closed car parked in the desert to those in the backpack of a serviceman on the arctic ice. The following types of containers are covered in this section:

- Three-piece (welded, soldered, nylon-bonded): round cylindrical; oval (plus variations, e.g. cooked ham can); trapezoidal tapered (corn beef can).
- Two-piece single or multiple drawn: round cylindrical; round tapered; rectangular (vertical wall); rectangular (tapered wall); square/rectangular tapered shallow trays.
- Two-piece draw and wall ironed: round cylindrical.

3.3.4 Ends for double seaming

Figure 3.2 shows the process of forming and curling the shell of an easy-open end. This shell will eventually be converted into a complete easy-open end by addition of an opening tab and scoring to the metal around the perimeter of the opening. In order that the formed shell can be removed from the press tool, the start curl, which will eventually form the curl, must be left straight. In the next process, the shape of the start curl is modified to a full curl to facilitate the formation of the final seam. From Fig. 3.2, it can be seen that the end consists of three functional areas: centre panel, countersink and seaming panel.

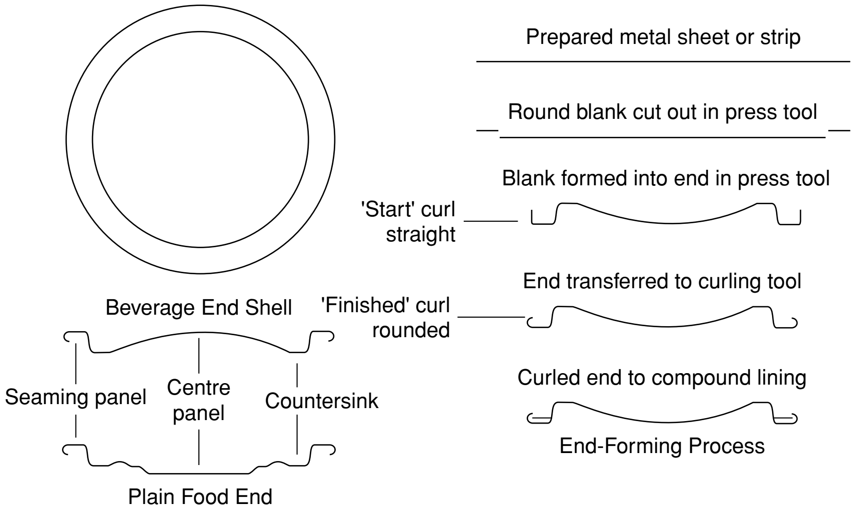


Figure 3.2 Beverage and food can ends. (Reproduced, with permission, from Page, B. (2001) *Metal Packaging: An Introduction*. Pira International.)

For a drink can end, which, after filling, is always at positive internal pressure, the centre panel is designed to contain the internal pressure of the can contents. This is prevented from blowing out under pressure by the metal in the countersink area: the deeper the countersink, the greater is the internal pressure resistance. The seaming panel is the area that forms the seal with the flange of the can body, after the two parts are rolled together. To aid in the generation of an hermetic seal between can and end, a liquid rubber lining compound is applied to the inside of the curl; this compound may be made from either solvent- or water-based materials but, in both cases, it must be given sufficient time to fully cure before being seamed onto a can body.

Processed food can ends, whether easy-open or plain (non-easy open), must be designed to withstand the heat process cycle described in Section 3.3.2. To give the necessary flexibility to the end to withstand the changing pressures over the cycle, and to prevent rupture at the point of maximum internal pressure, the centre panel has circumferential ribs and steps as shown in Fig. 3.2. The flexible centre panel design also allows the end to return to its original configuration after the contents have finally achieved ambient temperature at the end of the heating cycle. Failure to do this could falsely indicate that the can is ‘blown’ due to generation of gas pressure inside the can. When food can ends are designed for opening with a conventional can opener, the depth of the countersink area is limited to the depth of the cutting tool on the can opener.

Liquid lining compound is applied into the seaming panel area whilst the end is rotated at speed. This assists in flowing the compound and placing it in the correct part of the seaming panel area to suit the particular application. For drink cans, where the filled product is chemically very active, the compound is often placed ‘high on shoulder’ so that it fully seals the point inside the can where the flange and end butt up together, as depicted in Fig. 3.2.

3.3.5 Mechanical double seaming of ends onto can bodies

It is estimated that of the 410 billion metal containers made in the world every year, 99% include at least one double seam for heat process or pressure-containing purposes (processed food cans, drink cans and aerosols). After being established at the start of the twentieth century, the basic principles of this process remain essentially unchanged to this day. However, the demands of lightweight containers and high-speed filling lines now put extreme demands on seaming systems and operational controls to ensure trouble-free performance. The basic system of double seaming described below is the same for food, drink and aerosol cans.

Figure 3.3 demonstrates an end being offered to the can flange and the finished seam.

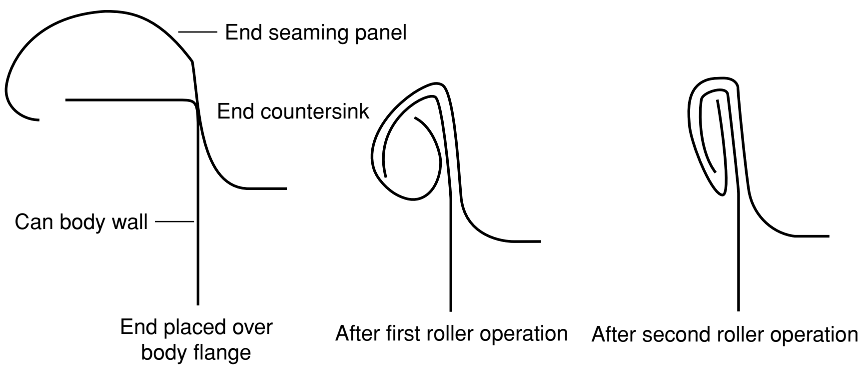


Figure 3.3 Double seaming process.

The inside diameter of the end curl is just sufficient for it to drop cleanly over the flange of the can. If the end were not curled, the two components would not lock together as the seam was made. During the seaming process, which is in two stages, the end is mounted on a circular chuck which fits the external surface of the countersink wall and supports this wall during the seaming process. The first-stage external roll rotates the seaming panel of the end with the can flange to close them up, as shown in the figure. The second-stage external roll tightens up the seam to give the correct final external dimensions. Both first and second stages are carried out in one seaming machine.

When double seams have been closed, it is necessary to analyse the dimensions to ensure that they have been formed correctly. Although some external dimensions can be taken from the outside of the finished seam, these are not sufficient for a full analysis. The latter can be done only by first cutting sections across the seams of sample cans and then measuring the various elements of the seam, as shown in Fig. 3.4.

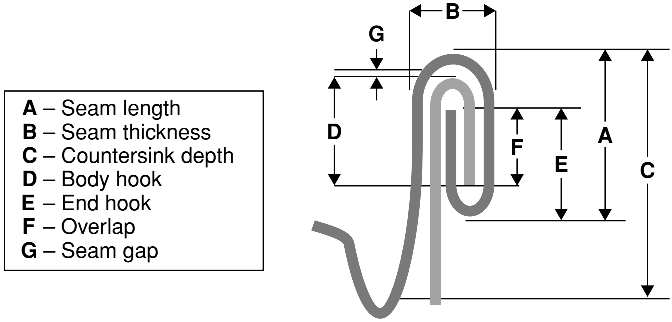


Figure 3.4 Double seam analysis. (Reproduced, with permission, from Page, B. (2001) *Metal Packaging: An Introduction*. Pira International.)

Relationships between these elements will indicate whether the overlaps, gaps, lengths and thicknesses within the seam are within specification or not. An instrument manufacturer in the United Kingdom now markets equipment that uses X-rays to view the cross section of the seam without the need for it to be sectioned first. This allows the seam to be examined while the container is under normal working conditions. In order to ensure the correct balance of dimensions within a double seam, it is important that the difference between the gauges of the end and flange metal are not too great.

The physical performance of a can end, in terms of its resistance to buckling due to excessive internal pressure, is affected by end metal thickness and temper, depth of countersink, tightness of seam and strength of the top wall of the can. For this reason, the top wall of thin-wall cans, such as those made by the two-piece draw and wall-ironing process, is often made thicker than that of the can mid-wall to give additional support to the end through the mechanical seam.

It is also important that the physical performance of the two ends of a can is similar, even if one of these is integral with the body in a two-piece can. If the two ends do not have a balanced performance, it is possible that in conditions of high internal pressure, the weaker end will take the entire expansion load and fail at an unacceptably low pressure.

One of the reasons that the double seamed joint has performed so well over so many years is its ability to tolerate flange contamination by the filled product without impairing seal integrity. It appears that the mechanical forces imparted to the metal in the seam are more than sufficient to make a good seam, in spite of the presence of foreign material on the face of the flange.

3.3.6 *Opening systems for double seamed ends*

The two previous sections describe the operation and double seaming of all ends of this type, regardless of the features that may have been added to assist in the eventual opening of the end. Double seamed ends are opened in a number of different ways: plain ends have no added features and therefore must be opened by use of an external tool. Until the development of the conventional rotary opener for food cans, it was necessary to use a special knife or maybe even a hammer and chisel. Modern rotary can openers are designed to cut either into the countersink of the end, which must be of the correct depth, or into the top wall of the can. Before the introduction of easy-open ends, plain ends for drink cans were opened by a Church key that by lever action on the can seam cut a 'V' section into the end. The existence of two cuts allowed the consumer to drink directly from one opening, whilst the other acted as a vent for the air.

Early shallow drawn fish cans had a separate key provided with which to tear off the lid at the same time as rolling it up around the key. Modern cans use a full-aperture easy-open end. Many trapezoidal corned beef cans also still use a system where a separate key is used to tear a complete strip around the can body to release the product from the tapered can. Full-aperture easy-open ends are now becoming available to replace this system.

The method of converting plain end shells into easy-open ends for food or drink cans is very similar. However, the performance requirements of the filled cans are very different. Food cans must be able to withstand the heat process cycle, and the end when opened must be suitable for removal of food products. Carbonated drink cans are always at positive internal pressure after seaming; they must be able to withstand high internal pressure due to the pasteurising process or high ambient temperature during storage, and the opening in the end must be convenient for the consumer to drink the product.

Conversion of a plain end shell into an easy-open end is a two-step operation – scoring the metal around the opening section and fixing the tear tab by riveting to the shell. Figure 3.5 shows a typical score detail where the external surface of the centre panel of the end has been partially cut through.

The thickness of metal remaining is termed the 'score residual'. In determining the amount of score residual for a particular end, it is necessary to strike a balance, which minimises the forces required to pop and tear off the panel, whilst leaving enough metal to ensure the integrity of the end. Because the tear forces for steel are greater than those for aluminium, the score residual for steel is normally less than that for an equivalent end made from aluminium. For this reason, easy-open ends for drink cans are usually made from aluminium. The tab is attached to the end shell by a rivet that is formed in the centre panel of the end (see Fig. 3.5). It is formed directly from the end metal to avoid any leakage of internal pressure from a pressurised can or ingress of air into a food can at negative internal pressure.

Easy-open ends for drink cans are made as either tear-off tab ends, where the tab and tear-off section are removed from the container, or as stay-on-tab (SOT) ends,

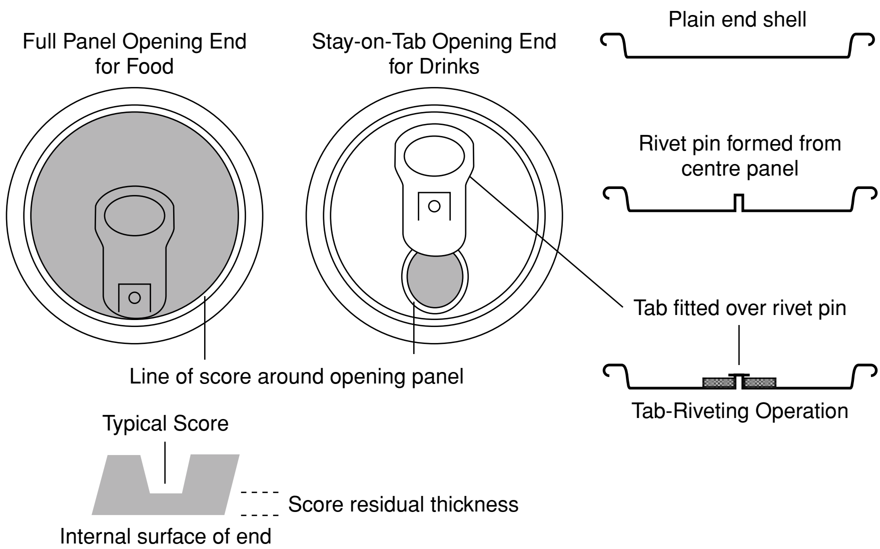


Figure 3.5 Easy-open end conversion. (Reproduced, with permission, from Page, B. (2001) *Metal Packaging: An Introduction*. Pira International.)

where the tab acts as a lever to open the tear-off section but the tab and tear-off section are retained on the container by the rivet. The shape of the tear-off section on SOT ends may be enlarged to that of a large opening end by providing a wider orifice to make it easier for the consumer to drink the product, as shown in Figs 3.6a and 3.6b.

Easy-open ends for food cans are, of necessity, full-aperture tear-off ends to allow for complete removal of the product. Much developmental work has been done over recent years to improve the ease of opening and safety aspects of these ends. Use of double-reduced tinplate of tin-free steel has helped to reduce the force required to tear the panel away from the support ring. Full-aperture ends (FOE) are made in varying cross-section shapes. Although the most common shape is round, rectangular ends are available for processed meat cans and shallow drawn fish cans. Oval and other similarly shaped FOEs are also used for like products. These are also shown in Figs 3.6a and 3.6c.

Where the consumer may wish to eat the product directly from the open can, the risk of injury from the cut edge remaining after removal of the opening panel on an FOE is reduced by forming an outward neck in the top of the can wall. This increases the diameter of the end, ensuring that the diameter of the cut edge of the end is greater than that of the can itself.

The aluminium alloy used for the manufacture of easy-open ends for drink cans is specially developed to give the required mechanical properties. This alloy is, however, subject to environmental stress cracking corrosion due to reaction with moisture. This process is also greatly accelerated by the presence of contaminants

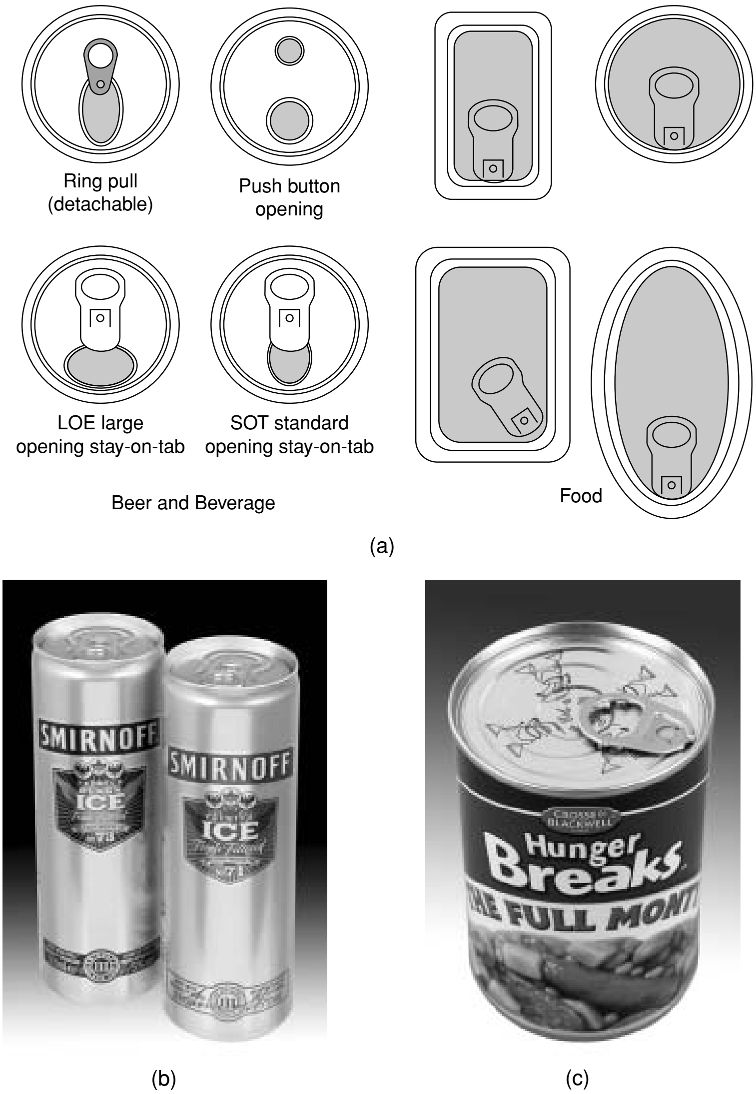


Figure 3.6 (a) Easy-open ends (Reproduced, with permission, from Page, *Metal Packaging: an introduction,* 2001, Pira International.); (b) Large opening end for drinks; (c) Full-aperture opening end for food.

such as residual salts, notably chlorides and halides. The score areas on both pull tab and stay-on-tab easy-open ends are particularly susceptible to this form of cracking corrosion because of the tensile stress to which this part of the end is subjected. This problem cannot occur without the presence of moisture, so great care must be taken after can filling such that easy-open can ends are thoroughly washed with clean water and dried before being put into store. Even during filled can storage, humidity conditions need to be controlled by provision of adequate ventilation, etc.

3.3.7 Heat-sealed lids for metal containers

Metal foil is used to provide heat-sealed closures for both food and drink containers. The foil may provide the complete closure, where the foil is sealed directly onto the can body. Alternatively, the foil may be heat sealed to cover a pre-formed aperture in a metal end, which will be eventually double seamed onto a metal container, or a container made of other materials such as coated board or plastic. In all cases, the components on either side of the heat-seal joint may be made from suitably coated/laminated aluminium or steel (tinplate/tin-free).

3.3.7.1 Lids heat sealed directly onto light-gauge metal can bodies

This system provides a lid that, when peeled from the container, provides an open aperture equal in size to the full cross section of the top of the container. It is used to close shallow drawn containers made from light-gauge aluminium or tinplate/tin-free steel for fully heat-processed foods such as pet food or human food snacks. The most common materials used to achieve a satisfactory heat seal are polypropylene film and heat-sealable lacquer, where the polypropylene film is laminated onto one of the can/end components whilst the lacquer is applied to the other. In practice, it has been found that certain heat-seal lacquers create difficulties with product removal after retorting. As the polypropylene film does not give this problem, the can body is normally made from metal with a polypropylene laminate film on the inside surface. The inside surface of the lid material then receives the heat-seal lacquer. As, in this system, the metal components of the lid and body do not come into contact with each other, there is no opportunity for bi-metal corrosion to take place between aluminium and steel during the heat-processing cycle. It is therefore possible to freely mix aluminium and steel lid and body components.

To construct a heat-seal joint suitable for heat processing, the flange face on the container is usually 4 mm wide. The metal around the outside of this is curled to hide and make safe the sharp metal edge and to provide an upstanding frame in which to locate the pre-cut lid when it is lowered into place. A typical shallow drawn tray cross section is shown in Fig. 3.7 together with a description of the heat-sealing process.

When fibrous products, such as meat, are filled into trays where the lid will be heat sealed, there is a risk of a fibre remaining across the flange face of the tray. This could then affect the integrity of the seal. One way of preventing this is to use a peelable diaphragm end, which is described below.

3.3.7.2 Double seamed end with integral heat-sealed peelable diaphragm

An alternative method of producing a heat-sealed joint on a metal container is to make a suitable aperture in a plain double seamed end and to cover this aperture

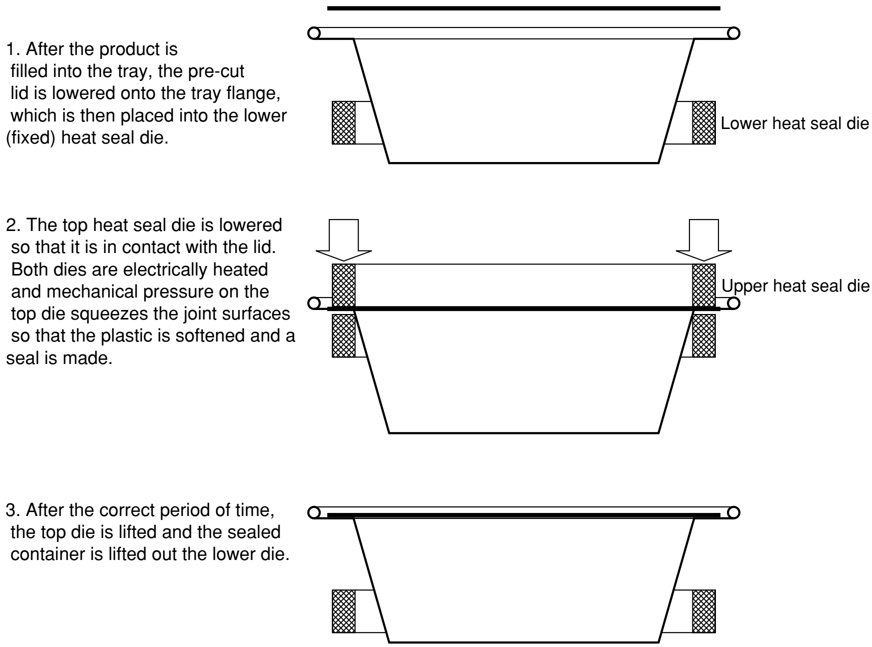


Figure 3.7 Shallow tray heat-sealing process. (Reproduced, with permission, from Page, B. (2001) *Metal Packaging: An Introduction*. Pira International.)

with a heat-sealed foil. Although costlier to make than a double seamed end or a lid seamed directly onto the container, this has the advantage that the heat-sealing operation is done in clean surroundings away from anything likely to contaminate the face of the heat seal. The final seam made onto the can body immediately after filling is then a conventional mechanical double seam (as described in Section 3.3.5), which can cope with contaminated can flanges.

A typical 'full-aperture' peelable diaphragm end is shown in Fig. 3.8a. This shows the process of taking a plain double seamed end, removing a section of the centre panel to create the aperture from which the product will be removed and placing and heat sealing a pre-cut foil lid. When the centre panel section is removed from the plain end, it is important to ensure that the metal edge remaining on the inside diameter of the ring is made safe and, if necessary, protected from contact with the product ultimately packed into the container – one way of achieving this is shown in Fig. 3.8a.

A rectangular cross-section food can with full-aperture peelable end is shown in Fig. 3.8b.

For liquid products, where a full opening aperture is not required, a small opening from which to decant or directly consume the product is sufficient. The shape of a foil lid for this type of end will be very similar in appearance to that of a tear-off tab on an easy-open end.

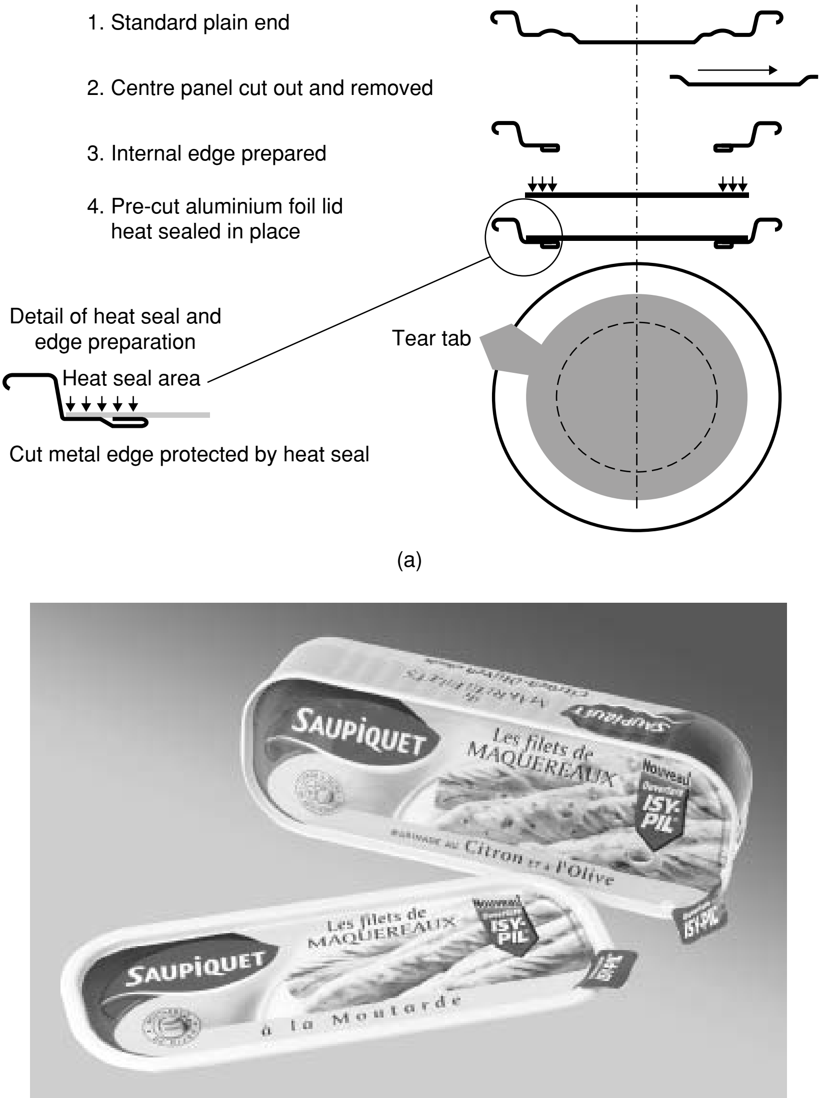


Figure 3.8 (a) Peelable end assembly (Reproduced, with permission, from Page, *Metal Packaging: an introduction,* 2001, Pira International.); (b) Peelable end for fish can.

3.3.8 Vacuum cans for food

A three-piece welded food can, where the lid is held in place by the internal vacuum (Dot-Top can), is in commercial use in Brazil. A plastic vacuum release button is fitted into an orifice punched through the centre panel of the lid. When the lip of this button is lifted, the internal vacuum is released, allowing easy removal of the lid. A diagram and photograph of this container are shown in Figs 3.15a and 3.15b.

3.3.9 Bottle-shaped re-sealable can for drinks with screw cap

A bottle-shaped two-piece drawn can, which has a conventional re-sealable roll-on aluminium cap fitted, has been introduced into the Japanese market. The container body, made from aluminium with polyethylene terephthalate (PET) laminate on both side, is initially formed from a DRD can body. The integral base is then punched through and formed into the bottle neck complete with rolled-in threads. A reverse dome base is finally double seamed onto the open end of the original can body. The internal surface of the cap is laminated with low-density polyethylene to provide a similar opening torque to that experienced on PET bottles.

3.4 Closures for GL performance containers (air/vacuum/liquid tight only)

3.4.1 Introduction and overview of section

This group of performance containers is used for liquids (which are pourable) and non-liquids (liquids, powders and pastes not pourable out of a small aperture). Those used for liquids such as oils and solvents have small apertures to better control the flow from the container. Cans for non-liquids such as water-based paint have large apertures to aid removal of the product. Typical products packed in these containers embrace food-grade cooking oils and powders, grease and lubricants, ink, paint, varnish, chemicals, fillers and pastes, solvents and hand cleansers.

For most of these containers, the lid must be re-sealable to prevent deterioration of the contents. The ability to completely drain or remove the product generally requires the closure to be completely removable. In some cases, the point where the lid is fixed onto the container body is specifically designed for this purpose.

Some containers in this group, when fitted with approved closures and triple seamed bases, are suitable for the transport of dangerous goods as defined in the UN Regulations and conforming to Packing Group II: medium danger with individual packaging up to 400 kg or 450 L. For these containers, mandatory tests are applied to ensure conformance with the regulations. These include drop tests to prove the integrity of filled containers.

The containers in this group are made from tinplate or blackplate, whilst the closures are made from tinplate for ease of forming. All food grade cans, and many of the industrial grade cans, are made from tinplate. These are generally printed with an external decorative label. To protect the user from injury from the sharp metal cut edges and to provide additional strength to the component, all unprotected metal edges are hemmed or curled. A hem is a simple fold giving protection but no additional strength. A full circular-section curl provides both protection and additional strength.

3.4.2 Types of containers to which these closures are fitted

By definition, general line performance containers and closures are designed to be liquid tight. As some of the liquids packed are very aggressive, to ensure an adequate liquid seal, the container body must be a welded three-piece can, a precision drawn two-piece can or a three-piece can with a lock seam that has been sealed with hot melt adhesive. The base ends of these three-piece cans are all attached by a full mechanical double seam, using the same principles as those used for food and drink cans, although not to the same precision. Lining compound must be used in the base seam when aggressive products are packed. However, compound is not needed, for example, for packs containing water-base paint.

Other than for diaphragm sealed or vacuum packs, containers in this group are not required to be pressure tight. In fact, for paint cans, there is some benefit in not applying a lining compound to the top lid ring in the simple lever lid system, as this allows air to escape when the lid is applied to the filled can. The degree of air tightness required by the closure system ultimately depends on the product packed. It should also be noted that screw caps have wads fitted or are lined to improve the seal tightness and prevent the product coming into contact with the material of the cap.

The following types of containers are covered in this section:

- Three-piece welded: round cylindrical cans; round conical pails; drums up to 30-litre capacity and non-round containers.
- Two-piece precision drawn: round conical pails and round and non-round tins with parallel sides.
- Three-piece lock seam with sealant: round cylindrical cans and non-round containers.

When describing the closures in common use with these containers, it will be seen that some closure types are used for more than one container type. To avoid duplication, each closure type will be described only once.

3.4.3 Round cylindrical cans (three- and two-piece)

3.4.3.1 Lever lid

The most common types of lever lid closures in use are shown in Fig. 3.9a. This closure comprises two parts: (i) a ring, where the major diameter embodies a seaming panel for mechanical double seaming to the can flange, and the minor diameter is folded to provide a tight push fit for the removable lid and (ii) a removable lid, which fits tightly into the ring, and where the outside diameter extends over the ring to provide a flange for use of a lever-opening tool.

A Lining compound may be omitted from the ring double seam to allow air to escape from the can when the lid is being automatically fitted by a pick-and-place unit. The lever lid, with normal headspace, may be fitted with an aluminium foil diaphragm to better preserve dry powder products and to provide tamper evidence.

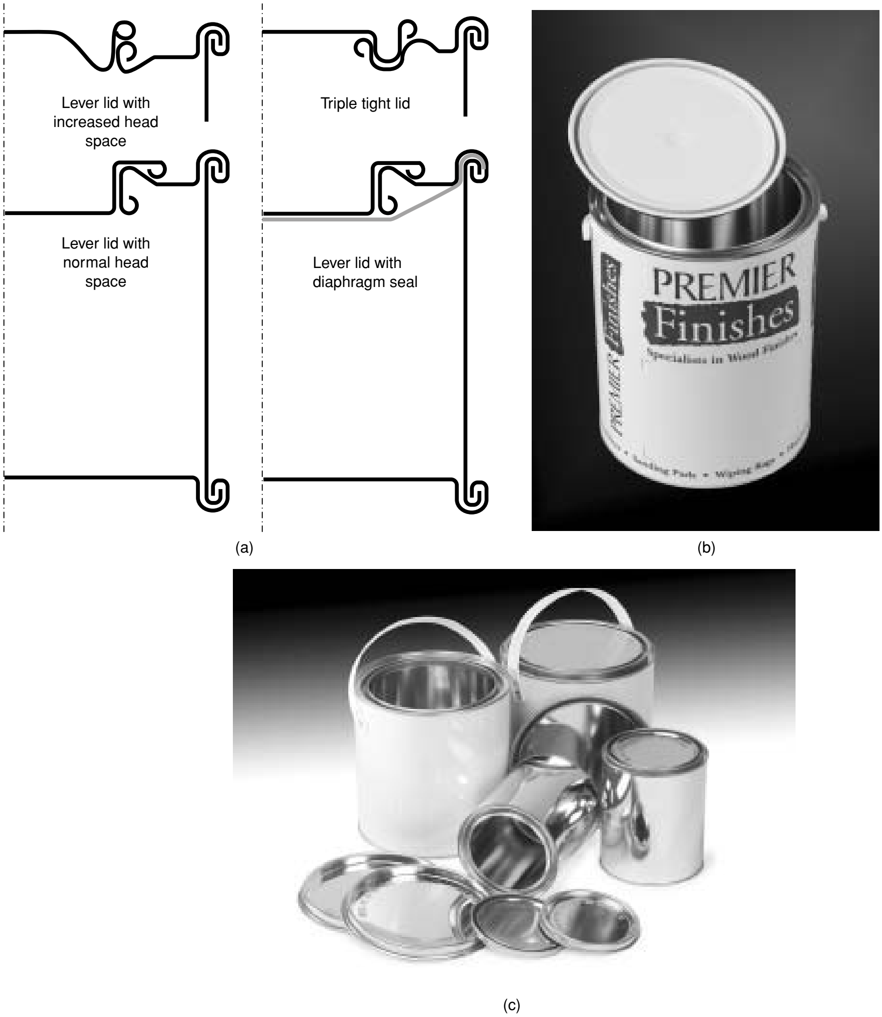


Figure 3.9 (a) Lever lid closures; (b) Lever lid paint can; (c) UN-certified lever lid containers.

For this container, the diaphragm foil is incorporated into the double seam of the lever lid ring by the can-maker. The plain base end is then seamed on by the filler.

To provide additional ullage at the top of the can, the centre panel of the lid is raised to be level with the top of the lid flange. This feature allows greater radial flexibility at the interface between lid and ring, and prevents the air at the top of the can being over-compressed during the automatic lid application process (particularly important for paint cans).

The triple tight lid has a better lid fit and is used for the more aggressive products such as automotive spray paints; it is not used for water-based paints. The features of this design prevent the lid from dipping into the product, and allow a paddle mixer to sit in the ring and be clamped to the container.

A standard lever lid paint can is shown in Fig. 3.9b, while Fig. 3.9c shows lever lid cans that are UN approved for the carriage of dangerous goods.

3.4.3.2 Plug lid

A plug lid provides an aperture equal to the diameter of the can body. The outer diameter of the lid and top edge of the can body are fully curled to provide the seal interface. The curl on the body may be formed in the inside or the outside of the can wall. An inside curl will provide a flush top to the can, whilst an outside curl will provide a flush inside body surface to aid in draining the can or scraping out non-liquid products such as fillers and pastes. Figure 3.10 illustrates the different combinations of curl position. A lever tool is normally required to remove a plug lid, as there is an interference fit between lid and body.

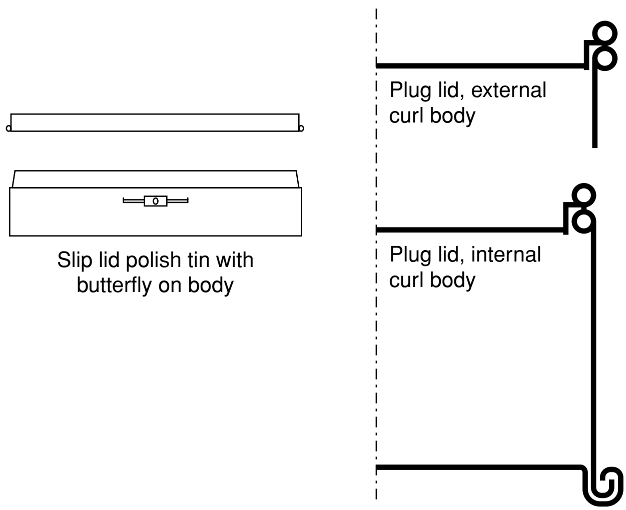


Figure 3.10 Plug lid and slip lid polish tin. (Reproduced, with permission, from Page, B. (2001) *Metal Packaging: An Introduction*. Pira International.)

3.4.3.3 Easy-open ends

Conventional full-aperture food-type easy-open ends, up to 150 mm in diameter, are available for use on GL round cans. One use of these is for packing printing ink, where this is vacuum-packed in a two-piece drawn can, to prevent skinning over.

3.4.3.4 Slip lid on drawn container body

A slip lid slides over the outside surface of the container wall. The fit between lid and wall is sufficient to prevent the lid from falling off accidentally and to make it easy to remove by hand. In the case of polish tins, shown in Fig. 3.10, the can wall is slightly tapered to tighten the fit as the lid is closed. To aid removal of the lid, a rotating butterfly lever is fixed to the can or lid wall. Variations in this design include snap-on slip lids and screw-on lids.

3.4.3.5 Double seamed end with circular aperture

A double seamed end with a circular aperture is used for liquid products. The top may be flat or slightly conical to take a moulded plastic closure or spout. Alternatively, the end may be formed into a deep cone and include a threaded section to accept a screw cap. The conical design ensures that all of the product can be easily removed from the container. These various designs are shown in Fig. 3.11.

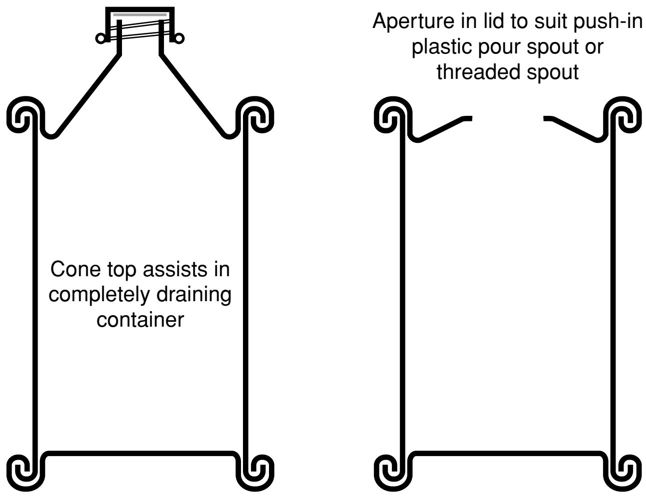


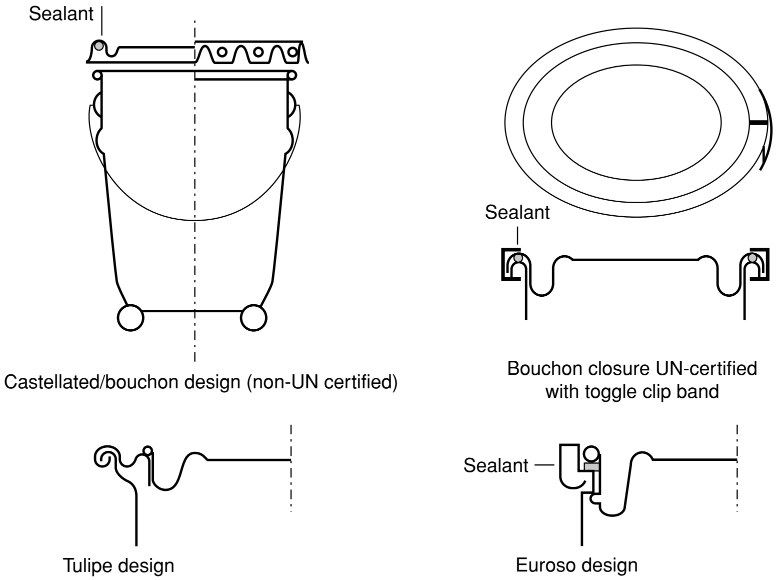
Figure 3.11 Cone top and closure for pouring spout.

3.4.4 Round conical pails – three-piece welded

These pails are mostly used for industrial products and have the benefit of the empty container being stackable to save storage space. The taper feature also makes it possible to stack the filled cans safely. The closures have locating studs formed into the inner countersink wall to ensure that the above pail is sitting centrally; they must also be designed to accept the increased axial load resulting from this. The fact that the closure may be completely removed from the top of the pail allows all product residues to be removed and, if necessary, for the container to be cleaned prior to recycling.

A hand pump unit is available for dispensing the products held in these tapered containers. The unit is mounted on a metal plate that sits on top of the product itself. A circular rubber diaphragm, attached to this plate, maintains contact with the sidewall as the product is removed.

There are a number of different designs of closures for this range of containers, some of which have locking bands to better secure the lid. The most commonly used systems are described in Fig. 3.12a.



(a)

(b)

Figure 3.12 (a) Tapered pail closures; (b) UN-certified pail with toggle clip band.

3.4.4.1 Castellated/bouchon design

The lugs on the outside of the closure have holes provided to act as lever points for prising them open before the lid can be removed. The edges of the lugs are curled to reduce the risk of injury. A special multi-finger tool is available for initial sealing of these lugs against the top wall of the pail. Sealant material is flowed into the closure to provide a hermetic joint with the rolled top of the body wall.

3.4.4.2 Tulipe design

The closure has a particularly large area of contact with the sealing ring and, as a result, will withstand the filled pail being tipped over from the vertical to the horizontal position without the lid opening itself. The sealing ring is double seamed onto the top wall of the container body.

3.4.4.3 Euroso design

In this pail design, the sealing ring is formed directly from the top wall of the container. Sealant material is placed under the outermost lip of the closure to form a joint with the top of the sealing ring.

3.4.4.4 UN design with toggle-type locking band

This container and closure carries UN certification for carriage of dangerous goods. To satisfy this certificate, among other requirements, the base is triple seamed onto the can body and the closure is held in place with a heavy-duty locking band shown in Figs 3.12a and 3.12b. Mandatory tests are applied to sample containers to ensure conformance. These include drop tests to ensure the integrity of filled containers.

3.4.5 Round-tapered two-piece drawn vacuum tins for ink

Two-piece drawn conical containers are used for vacuum packing of printing inks to prevent skinning over. The closure system for this, which embodies lining compound on the seal face of the lid, is shown in Fig. 3.15a.

3.4.6 Drums (up to 30-litre capacity)

Small drums are used for bulk storage and transportation of liquid products, such as lubricants and chemicals. For this reason, the top end is doubled seamed onto the body and contains a small aperture for filling and decanting the product. The bottom end has lining compound applied and is also double seamed onto the body. The different top end designs are shown in Fig. 3.13.

The flat top design incorporates a pierced opening to take the standard fittings used for rectangular cans as shown in Fig. 3.14, in addition to the Berg pull-out spout described in Fig. 3.16a. The flat top–screw neck design has a neck and external-screw-threaded aperture formed into top. The Tri-Sure version has an internal thread

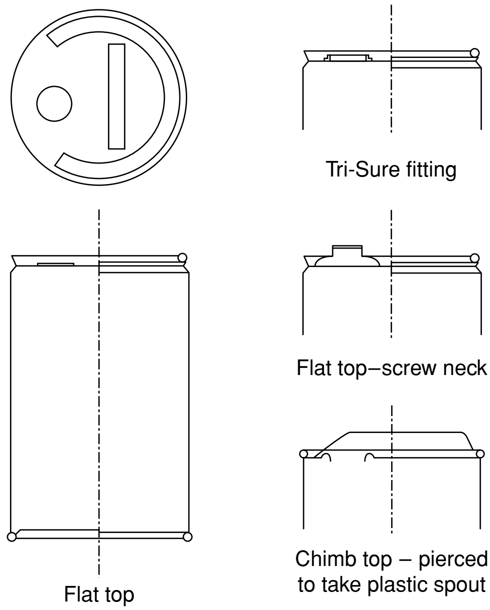


Figure 3.13 Small drum apertures.

formed to accept the special Tri-Sure bung. These three designs have a deep countersink in the top end to offset the high seaming forces. The top end is also necked in so that it will nest into the full diameter base of the drum stacked above. The deep well (countersink) also allows room for the closure, so that it does not come into contact with the base of the drum stacked above.

The chimb top design used in the United Kingdom also has a pierced aperture to accept the standard fittings used for rectangular cans, as shown in Fig. 3.14. In this top design, the chimb covers all the area of the top, except that of the well where the aperture is formed. Its purpose is to minimise the area of the top which can fill up with water.

3.4.7 Non-round containers

Non-round performance containers are made in either square or rectangular cross section, the latter being the most commonly used shape. Rectangular cans are convenient for retailers and consumers, because the shape allows them to be easily stacked side by side whilst occupying minimum shelf space. For the retailer, the flat surface also provides a large area on which to display the product label. These cans may be constructed with tapered sides, the larger end being at the base of the can, to permit one can to nest on the top of the other. Square or rectangular ends are double seamed onto the can wall, but with this method it is difficult to make satisfactory closures with wide openings. These ends are then generally provided with small apertures for pouring liquids, the size of the aperture being independent of the end size. As thick pourable liquids can hang up in the corners of a non-round can, these containers are normally used for low-viscosity liquids such as edible oils, motor oils or solvents. For this reason, the top and bottom end seams are always compound lined. The most commonly used aperture systems on non-round cans are standard diameter screw caps. For containers with less than 1-litre capacity, the neck for the screw is formed from the metal of the end. Containers above this capacity have an aperture punched inwards into which is fixed either a metal or a plastic insert. These aperture types are described in Fig. 3.14. Alternative apertures used on square containers are a large diameter screw-on cap, which uses an interrupted helix thread form, and a large-diameter opening lever lid.

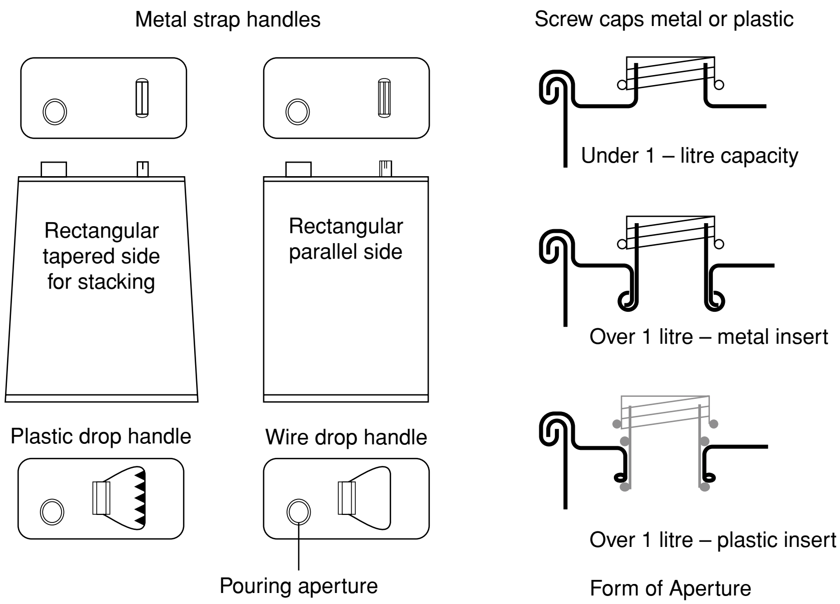


Figure 3.14 Non-round can closures. (Reproduced, with permission, from Page, B. (2001) *Metal Packaging: An Introduction*. Pira International.)

Rectangular cans above 2.5-litre capacity are provided with carrying handles fixed to the top end. The handles may be fixed straps or hinged wire/plastic drop handles. Where a fixed strap is provided, it is important that the height of the strap is the same as that of the top of the closure to allow cans to be stacked safely one on top of the other. Where a hinged drop handle is provided, it will fold down below the level of the top seam of the can. This will allow cans with a low-profile aperture to be stacked seam to seam.

3.4.8 Vacuum containers for tobacco (rectangular, round)

To retain product freshness in certain products, such as tobacco, or lozenges for medical use, it is necessary for the pack to be closed under vacuum. Two-piece round or rectangular shallow drawn containers are used for this purpose. The closures for these containers are made as either screw-on lids for round cans or slip lids for rectangular cans (see Fig. 3.15a). In both designs, lining compound is applied to the seal face to aid in retention of the vacuum. On the rectangular can, a coin or other lever tool must be used to release the vacuum when the container is first opened after filling.

3.4.9 Pour spout dispensing systems for GL performance containers

The Berg pull-out spout, referred to in Section 3.4.6, and shown in Fig. 3.16a, is a moulded plastic high-duty spout with close-fitting plastic screw closure. The spout is initially double folded so that the top of the screw cap is flush with the flat top drum closure into which it is inserted. Before use for the first time, the spout is pulled out to its full height; this spout cannot be collapsed again after use. Tins with these spouts are shown in Fig. 3.16b.

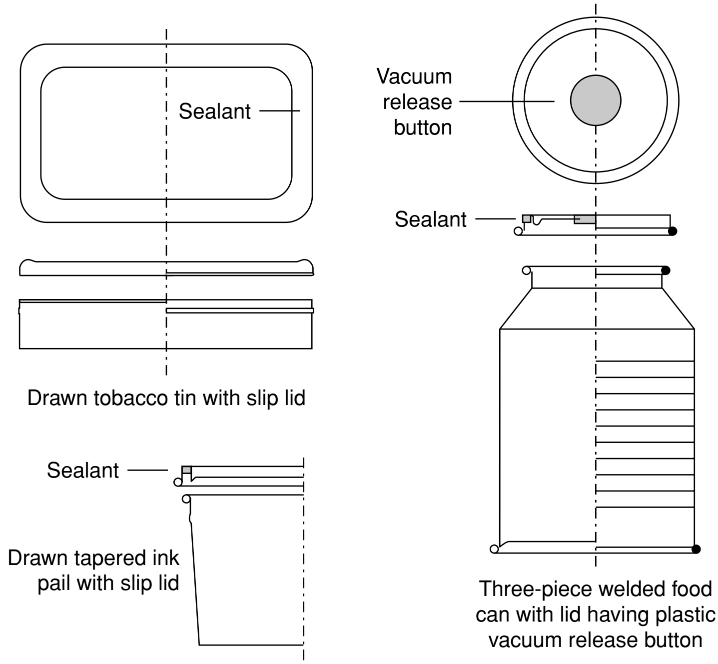
The Tri-Sure bung, also referred to in Section 3.4.6, is fitted to 205 L drums. In this system, there is a metal aperture fitting attached to the drum closure with a machined internal thread. The bung itself, which is also composed of metal, has a machined external thread to ensure a good fit and therefore adequate seal between the two parts.

The oil dropper spout is a plastic moulding that is a push fit into a pierced flat top closure used on circular or non-round GL performance containers (see Fig. 3.16a).

3.5 Closures for GL non-performance containers (not liquid tight)

3.5.1 Introduction and overview of section

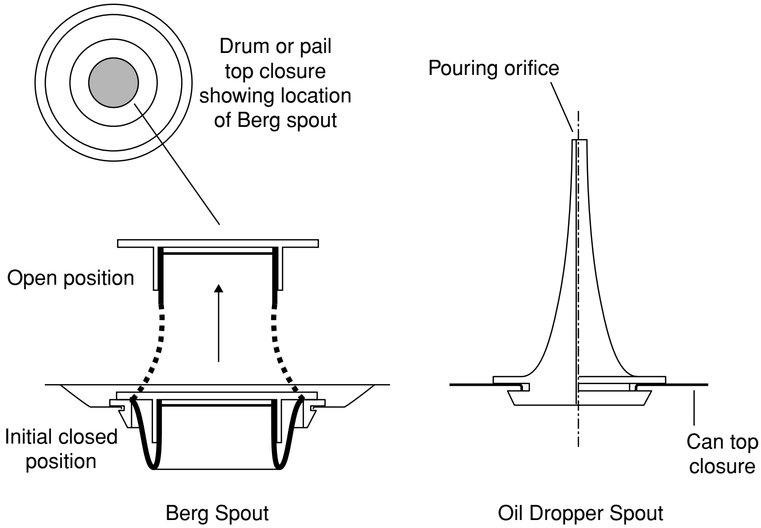
GL non-performance containers do not conform to any specific industry standards. Because most of these are designed as promotional products, outward appearance is normally more important than ability to perform to a particular technical standard, and for this reason, they are generally described as GL decorative containers. Nevertheless, the various closure systems used on these packages still have an important duty to perform, and their design and functionality is still critical. In all cases, the closures for these containers must be re-closable. For hinge boxes, the lid may need to function correctly over many years of use. With these containers, the importance of the outer decoration means that, for this purpose, the closure design is as critical as that of the can body and the closure decoration must also blend with that of the body.



(a)

(b)

Figure 3.15 (a) Vacuum can closures; (b) Dot-Top vacuum food can.



(a)

(b)

Figure 3.16 (a) Pour spout systems; (b) Tins with Berg pull-out spouts.

The majority of these containers are used as secondary packages, where the metal of the container does not come into direct contact with the product packed. Examples of these are the decorative can containing a glass bottle, which is itself filled with whisky, and the decorative lever lid can containing 'wrapped' boiled sweets. Those cans used as primary packaging may contain products, such as leaf tea, talcum powder, candle wax, cigars, pencils, crayons or artists' paint.

Mechanical seams used for non-performance containers are not fully formed as in a double seam. The seams here are produced by using only the first roll operation of a double seam system (see Fig. 3.3).

3.5.2 Types of containers to which these closures are fitted

Decorative GL containers have round or non-round cross sections, and are made from pre-printed/coated flat tinplate sheets. The can body-forming process may either be three-piece, using a lock seam without sealant, or two-piece, using a non-precision drawing process. For this range of cans, the term *non-round* covers many possible shapes, including rectangular, square, oval, triangular, hexagonal and octagonal. The bases of these cans are fixed to the sidewall with a simple mechanical seam, as shown in Fig. 3.17a. The seam is usually formed on the outside of the can, where it

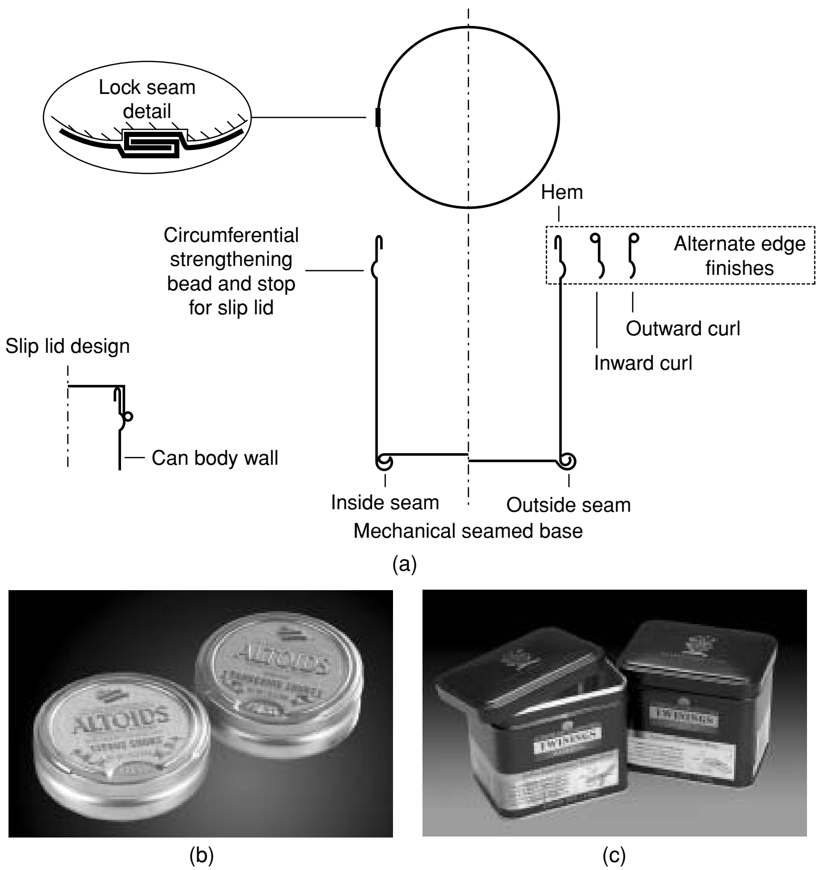


Figure 3.17 (a) GL non-performance lock seam and slip lids (Reproduced, with permission, from Page, *Metal Packaging: an introduction,* 2001, Pira International.); (b) Slip lid food tin; (c) Slip lid tin for tea.

has the appearance of a double seam on a performance food or drink can. However, as an alternative, the seam may be rolled inwards so that it is not visible when the can is standing upright.

The lids that form the closures are initially formed as shallow drawn two-piece cans. Special features are then added as necessary to provide the finished closure.

3.5.3 Types of closures fitted to GL decorative containers

Slip, plug, lever or dispensing lids may be fitted to containers of all cross sections, whereas hinge lids may be fitted only to square or rectangular shapes. It will be seen that many of these closure systems are also used on GL performance containers, where the standard of the closure will be more demanding. Although GL non-performance containers are also thought of as non-precision, the fit between lid and body is very important if the system is to perform correctly.

3.5.3.1 Slip lid

This is probably the most common design of closure used on GL non-performance containers. Figure 3.17a illustrates the range of design combinations in use. For both lid and body, the raw cut edge of the metal is hemmed or curled to make the metal edge safe, and to add strength to the component. In practice, a hem (folded edge) provides only a safe edge, whilst a fully curled edge provides both edge safety and strength. The variations in design are produced by altering the position of the hem or curl from the inside to the outside of the components. Further strength may be added to the top wall of the body by forming an external bead around all the sides. This bead also provides a surface for the lid to rest on when closed. For a slip lid to operate satisfactorily, there must be a slight interference fit between lid and body. The various design combinations are used to influence the outward appearance of the lidded container as much as to suit the closure performance. Two designs of slip lid are illustrated in Figs 3.17b and 3.17c.

Slip lids are not always sufficiently airtight for moisture-sensitive products, such as biscuits. For these products, to improve the sealing of the container, the filler will normally place self-adhesive tape around the outside of the joint between lid and body. For this to be successful, the external varnish used for lid and can body must be of the correct specification to accept the tape. For other products, such as leaf tea, where improved air tightness is required, an aluminium foil diaphragm may be placed across the can opening and then glued to the curled edge of the can wall.

3.5.3.2 Plug lid

The basic designs of plug lids for non-performance containers are the same as those used for performance containers, discussed in Section 3.4.3, and illustrated in Fig. 3.10. An additional variation of plug lid design is that used for biscuit barrels where a desiccant container is often embodied in the lid.

3.5.3.3 Lever lid

The basic designs of lever lids for non-performance containers are the same as those used for performance containers, discussed in Section 3.4.3, and illustrated in Figs. 3.9a and 3.9b. As the products packed into non-performance lever lid containers are usually dry in nature, the lid giving normal headspace is most commonly used. Lid cross sections used can vary to suit the different can shapes, the most commonly used being round or square.

3.5.3.4 Hinge lid

For many years, hinges between metal lids and bodies were formed with a length of wire inserted to create the hinge pin. The most common method now used is the 'lance-and-form' system where, after cutting out a small section of the lid sidewall adjacent to the curl, the remaining curl becomes the 'pin'. On the body of the container, a small flap is created, which is folded over the pin in the lid to create the 'hinge'. This method of hinge forming is shown in Fig. 3.18.

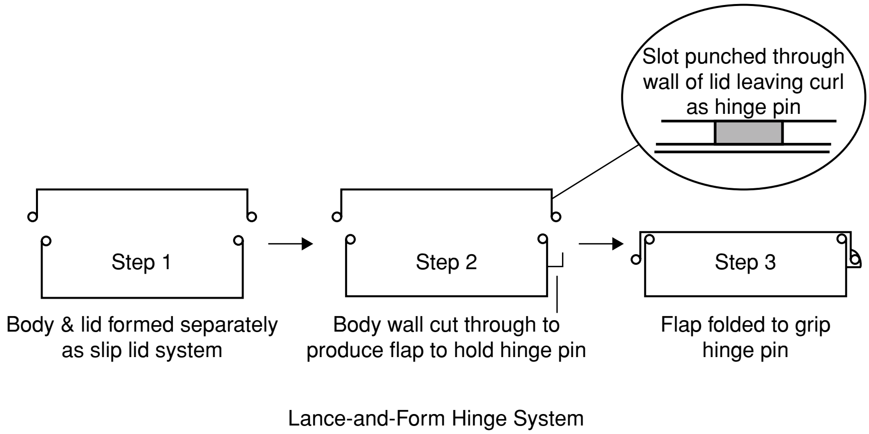


Figure 3.18 GL hinge lid closure. (Reproduced, with permission, from Page, B. (2001) *Metal Packaging: An Introduction*. Pira International.)

The components of a hinge lid container are very similar to those incorporating a slip lid. However, the clearance between lid and body is greater for the hinged container and a detent is formed in the top wall of the body to prevent the lid from opening accidentally.

3.5.3.5 Powder-dispensing systems

Powder-dispensing fittings may be incorporated into the top closure on GL non-performance containers; these may be constructed in metal or plastic and take the form of a cap with many holes for allowing the powder to pass through. The cap rotates on a circular base, which is clipped into the metal closure. Rotation of this cap by a few degrees opens or closes the dispensing holes. This dispensing system may also be attached as a push fit onto the prepared neck of aluminium two-piece impact-extruded aerosol body.

3.6 Conclusion

This chapter has reviewed the design of closures and sealing systems for performance and non-performance containers. It is clear that the standard required of sealing systems for performance containers, particularly where the filled and sealed can is subjected to heat processing to sterilise the contents, is extremely high. The point of sealing is usually the weakest point of the container and great care must be taken to ensure that the process of sealing is executed in the most diligent way, as failure to do this may put at risk the integrity of the whole container and its contents. The methods used for creating these seals are now very well understood, following experience over many years of production. The excellent record of safety of these products provides confirmation that the industry fully appreciates its responsibilities in these areas of technology.

It will be seen from other chapters in this book that metal closures are also used to seal containers made from glass, plastic and cartonboard. These may have preformed threads or threads that are rolled into the metal after a plain-walled cap has been placed over the threaded neck of the bottle. Alternatively, they may be provided with shaped lugs for attachment to glass jars. They may also form the ends of carton board tubes. In this case, the curled edge of the metal end is rolled onto the tube to form the base, while the top end is usually a plug fit end, as described earlier in this chapter.

New designs of containers continue to present challenges to the designers of closures for metal containers and, as an example, re-closable metal cans for drinks are now in the marketplace after many years of development. New material combinations, such as polymer-coated metals, will open the door to the design and manufacture of closures having new and evermore convenient features.

4 Closures for glass containers

Nigel Theobald

4.1 Introduction

Glass is the oldest of all the packaging forms used today, and probably took over from pottery as the container of choice for a multitude of products. Glass making is said to have begun as early as 7000 BC and was first industrialised in Egypt in 1500 BC. Glass was made by melting three base materials (silica, limestone and ash) and then moulded while hot. Glass making today still uses the same three basic materials; however, manufacturing techniques and skills have improved significantly, and vast leaps in glass-making capabilities are still being made in modern times.

Glass is manufactured from naturally occurring materials and, once formed, it is a robust container. Glass, in its pure state, is some ten times stronger than steel. The drawback is in the handling, where post-manufacture surface scratches and knocks reduce the strength of the container.

Glass is the most adaptable of containers in terms of the types of closure systems that can be employed to seal containers. Every type of material can be used to seal a glass container; most methods of sealing can also be used. With this in mind, glass should be considered one of the primary container choices for the modern packaging market. The closure choices are manifold, ranging from cloth through paper, foil and non-foil laminates, glass, steel, aluminium and plastics; any of these can be used to seal a glass container, given the correct neck design or treatment to affect the seal.

Glass can also be coloured or surface treated to achieve some stunning effects and give the added degree of individuality that is required by brand managers in their search for an individual image for their product. Different moulding techniques will achieve different results in the container, as well as having an effect on the sealing surfaces. Care must be exercised when deciding on the sealing systems; they must be compatible with the moulding process used for the container, and compatibility between the container and the closure system used is critical, as indeed it is with any of the packaging systems that are used.

There are many different types of glasses that are used throughout the glass industry. All are based on the main ingredients of silicon dioxide, soda ash and some other metal oxides to achieve the desired properties of the glass. The more common types of glass are as follows:

(1) Soda glass: silica sand, soda ash and limestone
(2) Lead glass: silica sand and lead oxide
(3) Borosilicate glass: silica sand, borosilicate and soda ash
(4) Solder glass: lead oxide, boric oxide and zinc oxide

Table 4.1 Proportions of materials used in composition of various types of glass

	Container	Plate	Table	Fibreglass	Borosilicate	Laser	Solder	Lead	Glass ceramic
SiO_2	70–74	71–74	71–74	65–74	70–82	68–69	0.5–16	35–70	62–70
Al_2O_3	1.5–2.5	1–2	0.5–2	2–4.5	2–7.5	0–5	0.1–4	0.5–2	17–22
B_2O_3				3–5.5	9–14		7–20		
Li_2O									3–5
Na_2O	13–16	12–15	13–15	8–16	3–8	12–14		4–8	
K_2O				0–1				5–10	
CaO	10–14	8–12	5.5–7.5	5–16	0.1–1.2	3–10			0–5
MgO			4–6.5	3–5.5					0–7
BaO					0–2.5		0–4		
ZnO							7–62		
PbO							4–77	12–60	
CuO							0–10		
Nd_2O_3						1–6			
CeO						0.1–1.1			
F_2							0–2		
TiO_2									3–10

Table 4.1 sets out the rough proportions of materials that are used for the different types of packaging and non-packaging glasses.

This chapter will consider the various closure systems available for glass containers, with a brief reference to the types of possible moulding systems that may be used. In common with every other type of container, new methods of manufacture and novel finishes will result in improvements to the final pack; this is particularly true with glass, given its familiarity to consumers. It is therefore important that the designer and specifier of packaging materials and components keep themselves up to date, not only with upcoming methods of manufacture, but also with the requisite legislative requirements for the products and the packs that are being specified. Legislation (apropos issues such as safety or recycling, for example) varies throughout the world and export requirements must be considered prior to choosing a pack. In order to set the scene for glass containers, it might be useful to list the relative advantages and disadvantages of glass.

4.2 SWOT analysis for glass

4.2.1 Strengths

- *High strength* – Glass has a high strength (higher than that of most other forms of packaging).
- *Sterilisation* – Glass can be sterilised by all the common forms of sterilisation processes.
- *High-quality image* – Glass is used for the higher quality end of the markets, as it has a superior image (in terms of luxury) to most other forms of packaging.
- *Returnable containers* – Due to its strength and weight, a glass container can be readily used as a multi-trip and/or refillable container.

- *Easily decorated* – Glass can be decorated with almost permanent decoration on the surface of the container, as well as by sleeving or labelling.
- *Recyclable* – Glass is probably the easiest material to recycle (both in actuality and in the eyes of consumers) and can be used both by itself and as a component within the mix for new glass containers. In addition, glass is 100% recyclable in a closed loop system, without any loss of quality.
- *Convenience in use* – Glass is convenient to use by the consumer, since it can be moulded into both wide- and narrow-neck containers; glass containers also exhibit rigidity, making the container easy to hold and dispense.
- *Barrier material* – Glass is completely impervious to both water and gases. This makes it an ideal material for oxygen- or moisture-sensitive products; it will also retain the water content within a product and not allow it to dry out in storage.
- *Easily cleaned* – Since glass is capable of withstanding high temperatures in both processing and use, it is easily cleaned. The high inertness of glass also makes it possible to use very aggressive cleaning materials in the process, without affecting the container quality.

4.2.2 Weaknesses

- *Weight* – Glass is probably the heaviest of the packaging materials commonly used for containers, and this will be reflected in higher transport costs per unit of distribution.
- *Brittleness* – The drop resistance of glass is lower than that of most other forms of packaging and, thus, added protection is required to ensure safe distribution without container failure. However, there is a school of thought that would argue that the visibility of the glass containers leads to better handling and less product breakage during transit.
- *Surface scratching* – Glass that has the surface scratched loses a marked proportion of its strength; this reduction of strength leads to an increased risk of shattering in the filling, transportation and storage operations.
- *Production line efficiency* – Due to the nature of glass and its brittleness, any chipping or damage in the production process at the filler does, of necessity, result in increasing the time on the production line, since the broken containers will need to be cleared from the line. The latter issue is particularly salient when glass containers are used for products that are liable to be eaten; strict line clearance procedures need to be enforced in order to avoid the contamination of other packs on the line from any shards of broken glass that result from breakage.

4.2.3 Opportunities

- *Image* – Glass portrays a high-quality image to the consumer, and thus there are many opportunities for premium materials suitable for many food and cosmetic products. Certainly, today's consumer trends reflect a move away from the instant, disposable mindset and move towards a luxury-loving and even extravagance lifestyle. Opportunities for glass are consequently on the increase!

- *Moulding* – The techniques for moulding glass are improving constantly and, with better methods of improving the neck finish, it is possible to increase the protection given to the product and increase the shelf life of products.
- *Surface coatings* – Glass can be surface coated to improve the scratch resistance, and thus can cope with increasing amounts of abuse while in transit or during use.
- *Decoration* – The ability of glass to be decorated with many different methods makes it a good medium for the presentation of many different products. Differing label applications can give a significantly different character to the final product, even when the base container is simply a 'standard' bottle.

4.2.4 Threats

- *Weight* – Glass is one of the heaviest packaging presentations. Thus, with the emphasis on weight as a criterion for packaging reduction in legislation, the glass container is a prime target for replacement. The use of lighter alternative materials may be driven by companies' need to achieve the weight-reduction targets laid down in the industry legislation.
- *Breakage* – Glass has a poor drop resistance and when it breaks there is a tendency for the glass to shatter into sharp shards. Most other packaging materials do not have this drawback. In addition, the injuries that may be caused by a broken glass bottle may limit its appeal in some situations (such as music festivals).
- *Plastics* – Plastics can provide an adequate replacement for glass containers, for a range of products. With the range of plastics ever increasing, as new materials and novel manufacturing technologies are invented, the threat of a takeover by plastics has become more pronounced.

4.3 Methods of manufacture of glass containers

4.3.1 Blow/blow

This is probably the oldest of the methods of mass production of glass containers. Previously, the hand-blown containers that were produced individually and thereby subject to considerable size variations (neck dimensions, wall thickness, etc.) were replaced, in the main, by the *blow/blow* process for mass production. In this process, the glass gob is cut from the parison (the ribbon of glass from the furnace) and blown into a mould to form the rough shape of the container; further blowing in a second mould produced the final shape of the container. Since the blowing is carried out on an external mould, the internal bore of the neck is controlled only by the amount of glass cut from the parison (the gob) and the distribution of the glass in the initial blow operation.

4.3.2 Press/blow

With this process, the gob of glass is initially pressed using a plunger into the rough shape of the container, with the final shape created by the blowing operation. With the press plunger in use, the internal bore of the neck of the container can be controlled more accurately, and better container dimensions can be achieved. The *press/blow* process is mainly used for wide-neck containers to enable a more uniform distribution of the glass.

4.3.3 Narrow-neck press blow

This process entails glass gobs being fed into blank moulds; plungers consequently form the neck of the container, with the blank mould constraining the external dimensions of the container and the plunger forming the internal bore. This gives a pre-form that can be transferred to the secondary moulds for the blowing operation whilst still molten; the method gives an even distribution of glass, with highly accurate neck dimensions; thus, an overall lower weight of glass is achievable.

4.4 Sealing methods

4.4.1 Simple seals

Glass containers, because of their inherent rigidity, can be sealed using a variety of methods. For example, where high-quality and low-volume preserves are sealed, this may comprise a thin membrane and a cloth cover held in place with a string tie or an elastic band. This type of packaging closure gives the impression of a quality ‘home made’ product and is mainly used for preserved products; the seals are not normally ‘fixed’ to the container but are ‘attached’ to it.

Another simple closure for a glass container is a glass seal. The latter is usually ground to fit snugly into the reamed neck of the container. An application of wax around the perimeter of the seal area will stop the glass stopper from falling out, and also improve the seal quality by sealing any imperfections in the glass-to-glass seal.

4.4.2 Crimp seals

4.4.2.1 Removable crimp seals

Crimp seals are one of the most commonly used methods of sealing glass containers; they are available as either removable or permanent seals, depending upon the closure type that is employed. Removable seals are most commonly seen by consumers as the foil seals on milk bottles, where the flat foil is pressed over the top of the bottle and crimped around the groove in the external surface of the neck of the container. The seal efficiency is remarkably high and the potential leakage of products can easily be resisted with this method of sealing. Removal of the seal is simple by pressing the centre of the foil – the resultant distortion of the foil releases the folds in the crimp and the foil can be removed. Clearly the choice of thickness of the foil is of paramount importance to enable a good seal to be affected and a good release ensured: too thick a foil can give a poor seal and poor release, and too thin a foil will lead to a risk of leakage and premature puncture.

4.4.2.2 Permanent crimp seals

In this type of closure, the seal is not intended to be removed and the materials used for application are much stronger and stiffer. The seal application technique is similar to that discussed above where the closure is crimped into the external groove in the container and differs only in the force required to form the crimp and the materials used. Examples of this type of seal are seen on pump and spray applicators.

4.4.3 Diaphragm seals

The intention of using these seals is to give a good seal to a container during the production, storage, transportation and sale of the product – in fact, at every stage of its 'life', right up to the time of first use. The seal is then ruptured to allow the use of the product, and a secondary seal will be required to allow the product to be sealed whilst in use. Different methods of sealing diaphragm seals may be utilised by the manufacturer.

4.4.3.1 Adhesive bond

In the case of this type of application, the filled container is passed under an adhesive roller that coats the top surface of the container with a layer of adhesive; the diaphragm is then applied to the adhesive coating. The diaphragm is usually a lining material that is in, and lightly attached to, a wad within a cap assembly. When the cap is screwed onto the container, the diaphragm comes into contact with the adhesive, and pressure is applied to the seal area by the screwing of the cap. Adhesive-applied diaphragms need time to allow the adhesive to 'stick' the membrane in place. When the cap is removed, the seal holding the diaphragm to the wad is broken, leaving the diaphragm still attached to the container. Removal of the diaphragm from the container is by puncturing it or peeling it off from the surface of the container. These seals are commonly used for dry food products, such as coffee. In this type of application, the seal also has the added advantage of acting as a type of tamper evidence to the consumer; once the seal is broken, the consumer can easily see that the container has been opened.

4.4.3.2 Induction welding

The application of the seal membrane is much the same as the process for adhesive bond outlined above; the difference being that, instead of applying an adhesive to the neck of the container, the container itself is treated to accept the thermoplastic layer that is on the diaphragm membrane. The filled container is therefore capped with the diaphragm inside the cap assembly and then passed through a machine that applies an induction heating operation to the cap assembly. The resulting heat melts the thermoplastic layer that adheres to the upper surface of the container and, as soon as it is cooled, the seal is effective. This technique may also, like the previous one, be used for dry food products; however, it can also be used for wet products, provided that the seal area is not contaminated with product or moisture.

4.4.3.3 Radio frequency welding

This is similar to the preceding induction welding process, except that the sealing action is affected by radio frequency (RF) waves instead of induction heating. The heating provided by the RF waves cause the molecules of the seal to vibrate, and the resultant friction that arises at the seal surface causes heat to be generated and the sealing medium to become active.

4.4.4 Corks and bungs

4.4.4.1 Corks

Cork has been used as a seal for bottles almost since the invention of the blowing process for glass container manufacture. The ability of the reasonably accurate cutting and shaping of the bark from the cork tree, coupled with its ability to compress or deform to fill an irregular shape, made it the ideal material for the non-precision of the blown inner bore of the blown bottles. Cork also has the ability to exert a pressure on the glass container (especially when wet) that will enable it to maintain a good seal, even with internal pressures.

Corks have been used by the wine trade for hundreds of years; wine merchants typically store wine bottles on their sides, since this allows the cork to remain wet over long periods of time whilst in the store (or cellar). Although the inner surface (which is in contact with the wine) remains wet, the cork on its outer surface tends to be dry. The ability of the cork to give a low rate of moisture transmission makes it ideal for wine storage, as cork has the ability to deform well to the irregularities of the container, while maintaining a good seal.

Other materials (such as plastic) may be used effectively as stoppers in bottles. Although these will function effectively, they are not considered to be aesthetically pleasing. However, plastic materials do have an advantage over cork, as they can be shaped/sized more accurately, and with modern precision in bottle bore control, they are well suited to high-speed production lines. ‘Plastic corks’ have a similar appearance to the traditional cork and have the advantage that their size stability is maintained in both the wet and dry states. This enables the bottle storage to be in either the upright position or lying down.

Traditionally corks have been used for sparkling wines (including champagne), as they are able to expand when they come into contact with the product. This means that the correct shape of the bottle neck (with a taper where the top of the neck is smaller than the lower portion) will provide a higher resistance to removal than could be achieved with a straight-sided bung. With the addition of the external wire retainer, the seal assembly is complete and secure.

4.4.4.2 Bungs

Plastic bungs differ from the plastic corks in so far as they have a different profile. The bung usually has some means of compensating for small irregularities in the neck profile of the container and also a means of making the extraction of the bung harder. This is usually in the form of fins that are attached to the circumference of the bung (Fig. 4.1). Rubber and PVC are two of the common materials used here. The same principles apply here as those for cork: the material needs to be flexible enough to fill any imperfections in the bore of the bottle, but resilient enough to withstand the possibility of the product pushing the bung from the mouth of the bottle. Any material used for a bung needs to be resilient and to give good resistance to moisture loss or gas penetration. Interaction with the product and/or the container is another important consideration. Any material used for the bung will come into direct contact with the product and the container and thus must be shown to be compatible with them. Leaching of component ingredients of the bung must be limited and should conform, where relevant, to the legislation that exists for leaching from packaging materials. Since the bung is in contact with the product, any surface lubricants that are used in the manufacture of the bung must be compatible with the product. Surface lubricants are sometimes used to allow the bung to be more freely pushed into the

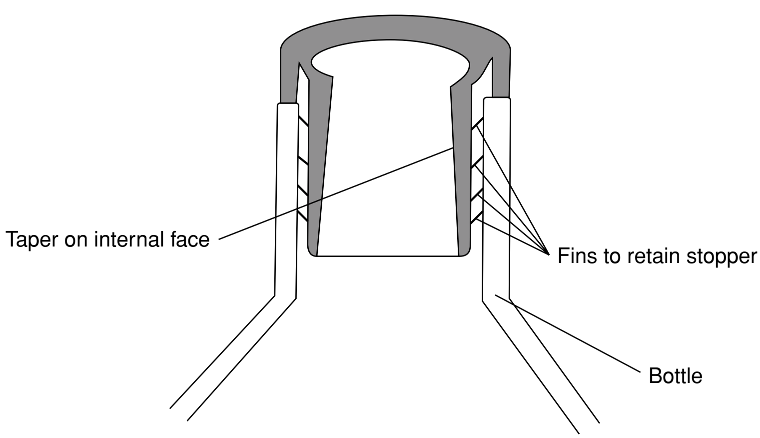


Figure 4.1 Sketch of plastic bung.

bottle neck and thus assist with higher speeds on production lines. Care should be taken to ensure that these materials do not cause adverse effects with the product.

4.4.5 Crown corks

Crown corks are one of the earlier forms of closures for bottles. The original type of crown cork was a tinplate cap, lined with a cork liner. This was placed over the bottle neck and crimped into position. The crimping action exerted pressure onto the cork liner and thus the cork moulded itself into the irregularities of the bottle neck. This type of closure was effective with the bottle where the split line of the blow moulds gave a thin trace line over the top of the bottle mouth (line over finish). The cork could then be deformed to mould around the finish line and effectively seal the bottle, even where the product exerted an internal pressure on the seal. The bottle moulding needed to have a retaining ring moulded in, so that the crown cork could be crimped under the ring to retain it on the bottle.

Since the initial use of cork liners, different materials have been used to achieve a suitable seal. These are, typically, board liners coated with various surface coating or laminates to give the desired product and environmental resistance. The board used is capable of deformation under compression, as it is of sufficient thickness and density to deform under pressure and will, as with the cork, form a good seal over an irregular surface of the bottle. Crown corks are a single-use seal as, once removed, they are difficult to replace.

4.4.6 Screw caps

4.4.6.1 Push on–twist off caps

These caps are tinplate, aluminium or plastic based, but all have similar attributes and modus operandi. The basic principle is that the caps have flowed-in liners that allow the cap to be pushed on in the filling and closing of the container on the production line, but can be twisted to remove during use. The cap can then be reapplied in use by twisting it back on. Special requirements for this type of cap are concerned with the thread formation and the position of the flowed-in liner. The thread on the bottle is not a continuous thread, but a series of short-angled protrusions on the outer surface of the bottle neck. The cap has a flowed-in liner that is placed partially down the side of the inner surface of the cap and over the area that will come in contact with the upper surface of the container. It must be sufficiently thick to take up the bottle ‘thread’ protrusions. During production (on the filling line) the cap is pushed onto the bottle and the liner of the cap deforms around the bottle ‘threads’ and across the top of the bottle. This retains the cap in place. To remove during use, all that is required is that the cap is twisted off in exactly the same way as if the full threaded cap and bottle were being used. Reapplying the cap is by twisting it back on as if it were a normal thread. Usually the screwing action to remove or reapply is less than a single turn. Different materials, however, can have different systems for sealing and these are discussed below.

4.4.6.2 Tinplate caps

Tinplate is used extensively for the sealing of glass containers, mainly for products in the food trade – items such as jams and conserves. Additionally, wet baby foods and sterile products may use tinplate caps. Most of the applications are for hot-filled products where, on cooling, a vacuum forms within the container headspace. The advantage of the tinplate cap is that it has the ability (if properly designed) to deform as the vacuum increases. Thus, when initially applied, the cap cross section is one of a convex nature. With the cooling of the product and the resultant increase in vacuum within the headspace, the cap is forced into a concave cross section. When the cap is removed the release of the vacuum in the headspace allows the cap to resort to its original convex shape and the familiar ‘pop’ is heard (Fig. 4.2).

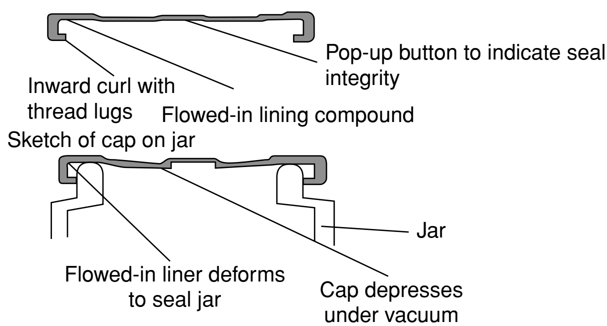


Figure 4.2 Sketch of tinplate cap.

Most of the cap profiles are screw caps, since the caps are required to be replaced during use. The majority of these caps have flowed-in liners around the area where the seal is to be made; this allows for any minor imperfections of either container or cap to be negated and give a good seal. It should be remembered that the constituents of the flowed-in liner must be compatible with the product and adhere well to the tinplate of the cap. Hence, most tinplate caps have a lacquer applied to the inner surface of the cap to stop any interaction between the tinplate and the product. Different liner materials may be used, depending on the nature of the product inside.

Since the containers are usually capped whilst the product is still hot (so that a headspace vacuum is created on cooling), the tinplate cap and the flowed-in liner must be capable of resisting the effects of hot steam and the condensate that results on cooling.

4.4.6.3 Aluminium caps

Aluminium is used where the benefit of its ductility is required, and hence is mainly used for *roll-on pilfer-proof* (*ROPP*) *caps*. It should be stressed that, in practice, there is no such thing as pilfer proof, only tamper evidence, and there have been cases of a ROPP cap applied to glass whisky bottles where the product has been replaced with cold tea, with no evidence of entry between the cap and the bottle. Care should always be taken not to assume that a product can be protected from the determined tamperer, even with the most basic equipment (Fig. 4.3).

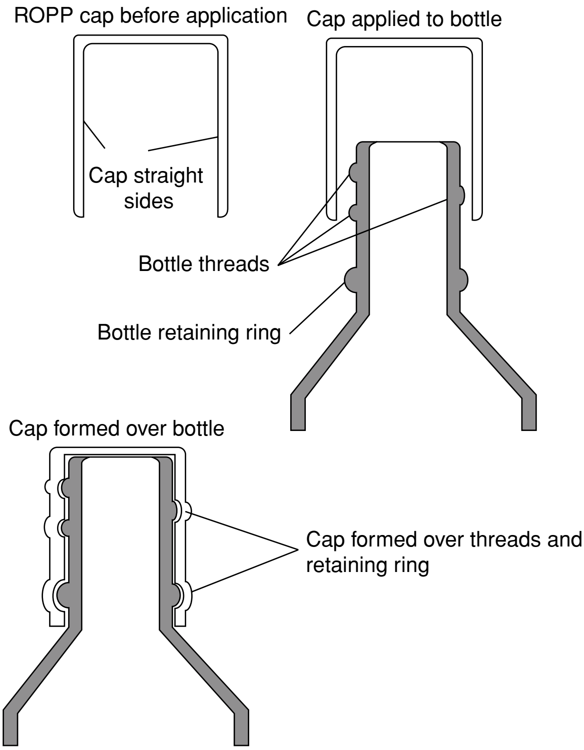


Figure 4.3 Sketch of ROPP cap.

A ROPP cap is applied as a cap with a cylindrical cross section and no thread. On application, the cap is distorted over the thread of the bottle, and the base of the cap is deformed around a securing ring in the bottle neck. In order to secure a good seal, liners are usually used, either as a flowed-in liner or as a wad. In the case of the wad, the material may be a board of expanded plastics (expanded polyethylene or expanded polystyrene) coated or laminated with the appropriate membrane (i.e. one that will achieve the desired moisture/gas barrier for the product protection and shelf life). Aluminium can also be used as a crimp seal for a cap, but this is a standard practice, as there is a tendency for the cap to split on crimping. Many caps are used as spun seals where the seal is achieved by a similar process to that used in seaming the end of a tinplate can (see Chapter 3: Closures for metal containers).

4.4.6.4 Plastic caps

Plastic is commonly used for caps for glass containers and there are many different types of seals available. Many of these are described in more detail in Chapter 6. Perhaps, it is suffice to say here that most of the caps and seals described in Chapter 6 would also be relevant to sealing for a glass container.

The caps may be wadless, as shown in Fig. 4.4, or of the wadded variety. Different orifices are also available to give the desired pattern for discharge of the product. As with any closure and container, the thread forms must be compatible with each other, and different thread forms exist for plastic or metal caps. As plastic materials normally tend to have a lower coefficient of friction, a specific thread pattern will reflect this so as to reduce the tendency to 'back off' post-production. 'Back off' is usually associated with temperature cycling in store or transport. Since the temperature will change markedly in many countries between night and day, there can be a loosening of the cap on the bottle if the thread profiles are not exactly compatible. This is caused by the materials expanding as the temperature rises and the two components 'slipping' over each other as the pressure on the contact points increases. As the temperature reduces the pressure is reduced and a loosening of the thread results (known as 'backing off'). This is, to some extent, due to the different coefficient of expansion between the glass and the plastic of the cap.

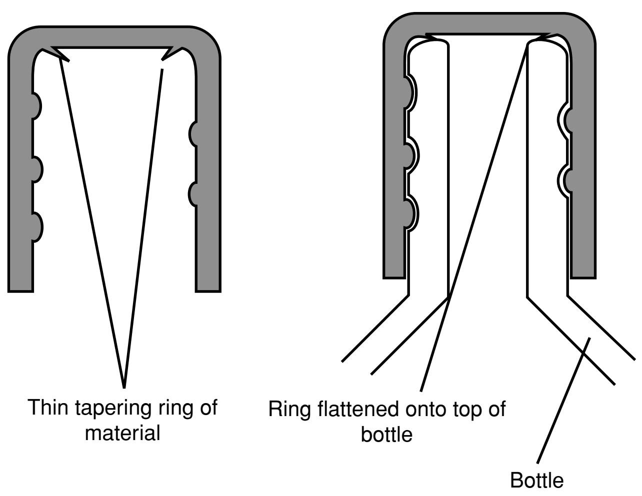


Figure 4.4 Sketch of wadless plastic cap.

4.4.6.5 Ring pull

As with metal containers, the glass container can be fitted with a ring-pull closure for the convenience of the consumer. These are, of course, use-once products, as the ring pull closure cannot be replaced. Where further use is required, it is possible to fit over the top of the ring pull a secondary cap that will allow a seal to be made.

There are some ring-pull devices that are used as tamper evidence systems and are used on plastic closures where the ring pull is part of a secondary feature inserted into the neck of the container.

4.4.7 Child resistance

Child resistance is a great concern to the technologist and should always be considered where there is a potential danger to a child from the ingestion of the product, or of a danger to health by the product coming into contact with the skin. Even breathing the vapour from a product could be hazardous in some instances (where the consumer is asthmatic or the products are flammable). In such cases a child-resistant closure (CRC) should be considered. The concept, need and testing of CRC closures is dealt with more details in Chapter 9. Child-resistant caps are required by law in some countries and the regulations vary from country to country; thus, care needs to be exercised when choosing a closure to ensure that the legal requirements of the country to which it is being exported are adhered to.

4.4.8 Dispensing systems

4.4.8.1 Rotary systems

Rotary dispensers can be added to a glass container in the same way as with a can (where they are pushed on to a pre-formed lip on the container). These applicators, which are predominantly used for the cosmetics and toiletries market, allow for the dispensing of powdered products from the container, as well as the effective sealing of the container after dispensing. Most rotary dispensers are two-piece dispensers, with the internal part sealing on the container and the outer part sealing on the inner section of the closure. By twisting the outer part of the closure the dispensing holes in the inner portion and the outer portion line up to dispense powder.

4.4.8.2 Shake dispensers

This is essentially a different name for the rotary dispenser with a more easily understood method required to dispense the product. However, there is an alternative to the rotary action where the lid on the cap, which covers the dispensing holes, can be lifted (instead of rotated) and the dispensing holes revealed. Careful moulding of the cap (usually a one-piece cap) is required, with care during the operation of the injection moulding cycle to control the shrinkage on cooling and maintain a good ‘snap’ fit of the lid to the body of the cap.

4.4.8.3 Plug

For this type of closure, the cap, in addition to being secured to the outer side of the bottle neck, also fits within the bore of the neck. This system allows the bottle neck to remain clean during transport and after each use. Moreover, it gives added seal area for some of the more critical products. Careful tapering of the inner seal needs to be considered so that the plug will fit within the confines of the neck bore, but will still give a good seal when fully pressed home.

4.4.8.4 Anti-drip

Anti-drip is a refinement on the plug feature, and may be inserted as part of the cap assembly or as a separate item. Where it is a part of the cap assembly, the anti-drip feature is attached to the cap during the moulding process (usually for plastic caps) and inserted with the cap. However, an anti-drip can be incorporated into other caps with different materials. In these instances, the anti-drip can be manufactured separately and inserted into the cap prior to the cap being placed on the bottle, or it can be inserted into the bottle neck on the packing line, just prior to the capping operation. Two possibilities thus exist: the anti-drip dispenser can either be pressed home prior to capping or just located in the neck bore for the capping operation to push it fully home.

The purpose of the anti-drip feature is to ensure a clean dispensing of the product; many products (in differing applications), when they ‘contaminate’ the thread of the container, cause problems for further dispensing. The product around the thread may become sticky and make the cap difficult to remove, or it may attack the material of the cap and corrode it to such an extent that the cap becomes useless; other products, such as those with a high sugar content, also show the above characteristics. Highly acidic products (vinegar and sauces, for example) corrode the caps and make them useless and dangerous to unscrew, leading, potentially, to a packaging-related accident involving injury to the hands.

4.4.9 Pumps

Pumps used for glass containers can be of different types, depending on the final application required by the manufacturer of the product – or of the desired effect from the pump. Glass containers can be pressurised, and so an aerosol spray effect is possible from this type of container. Some of the applications that are possible are described below, but new technologies are constantly emerging to allow for different applications and pump actions for a variety of novel products, and it is up to the individual technologist to see what is possible and not just what has been achieved.

4.4.9.1 Aerosol pumps

In this case, the container needs to be pressurised to achieve a satisfactory spray from the aerosol. Due to both the nature of the products typically used in this area and the fact that the container is pressurised, it is normal for this type of pump to have a crimp seal. This will give manufacturers a reasonable feeling of reassurance that the pump will not be removed while the product is still in the container (and consequently under pressure). For added safety, a pressurised glass container has an added film barrier on the outside of the container. This is to help contain any explosion in the event of the container breakage. With pressurised containers, any slight leakage from the seal will result in, at best, a loss of pressure from the container (thus premature loss of dispensing of the product – customer dissatisfaction) through to, at worst, a serious fire and loss of life. It is emphasised that pressurised containers must be 100% inspected and checked for leakage to avoid any discharge of pressurised gas or product.

4.4.9.2 Pump pack (lever and push button)

For this type of closure, the pump is added to the neck of the container, and can be crimped on or screwed on. This is usually dependent on the final requirements for the pack, or the availability of equipment on a packing line. Crimps on pumps are not intended to be refilled, whereas the screwed on pumps can, if desired, be refilled. Many pump packs use a dip tube in the pump to draw the product from the bottom of the container. By pressing the pump (either lever pump or push button), the product is forced up the dip tube and through the nozzle of the pump as a spray or jet of product.

4.4.9.3 Pumps (pressure priming)

It is possible to produce an aerosol spray using a pump pack, but without the necessity to have the container pre-pressurised at the factory, with the propellant. With this type of pack, the pump is incorporated within the cap assembly and used by the consumer to prime the pressurisation of the container with air. This has the advantage of not requiring such rigorous testing within the factory environment, nor in the storage and distribution systems. The consumer, prior to first use of the product, uses the pump attachment on the cap assembly to prime the pack. This is usually pumped until the consumers cannot pump any more because of the back pressure that they have created within the container. The pack (and product) is now ready for use. After spraying (using) the product, the consumer replaces the pump body back onto the cap assembly, thereby pumping more air into the container. This action may well be sufficient to give the necessary pressure increase in the container that was lost during the spraying operation. As the propellant is air, rather than a liquid hydrocarbon, the pressure drop during spraying is more noticeable and may result in a higher variation of particle size in the spray during the spraying operation. However, this can be negated by frequent pumping during longer periods of spraying. This system does allow for the pack to be refilled and, over a period of time, the increased cost of the pump assembly can be offset by the possibility of repeat use.

4.4.10 Vials/ampoules

Glass is one of the few materials where the container and the closure can be made from the same material, the whole forming just one piece. It is also possible for some plastic processing plants to achieve this application as an aseptic filling line (form/fill/seal lines). With glass, however, it can be achieved as a sterile filling operation, as well as an aseptic operation.

With the glass vial, the normal operation is to produce a glass tube and to seal it at one end by forming the near molten glass into the end of the vial. At this stage, the top is also constricted to form the neck of the vial. The product is then filled, and the upper part of the neck heated until it is red hot. It is then drawn into the shape of the vial with a constricted neck and closed and the vial is cooled. A weak point on the neck is introduced by cutting partially through the glass at the requisite point, so that, while in use, the neck can be snapped off. This allows, for example, a hypodermic syringe to be introduced and the product withdrawn.

4.4.11 Spun seals

This type of seal is similar to that of the seaming on a can, where the container is spun around a shaped forming tool to produce a seal that is similar in appearance to that of a crimp seal, but without the creases. This is a seal using an aluminium cap and produces a seal that is non-removable. Adaptations of this seal can be seen on pharmaceutical products designed for injection, where a rubber membrane is sealed using a spin seal outer aluminium ring. The outer ring holds the rubber diaphragm in place and allows the user to insert the hypodermic syringe through the rubber to fill the syringe. When the syringe is extracted, the rubber membrane closes around the hole made by the syringe, resulting in a complete seal; the container is now ready for the next insertion.

4.5 Conclusion

Glass is one of the most adaptable of materials to form and produce different containers for a variety of different products. It displays the qualities of luxury and efficiency in production and use. Glass is also the most widely accepted material for recycling.

Glass recycling in the United Kingdom is now 38%, with that in the United States being 25% and countries such as Switzerland achieving 95%. The new targets for the European Union (to achieve by 2008) are for a 60% recycle rate. In the United Kingdom, some 3.5 billion glass bottles are recycled, compared with 1 billon plastic bottles, 2 billion aluminium cans and 2.5 billion steel cans. In the United States, glass is behind other materials in the recycling stakes (cardboard 71%, newspapers 59%, steel cans 57%, aluminium cans 55% and plastic bottles 32%), but this is mainly due to the lack of recycling facilities within a reasonable delivery area. As well as being fully recyclable, glass can, in the recycled state, be used for many of its former uses, unlike fibreboard (destruction of fibre length and contamination in recycling) or metals (where contamination between different metals is a problem) or plastics (where the multitude of polymer types and differentiation is a problem). However, whilst extolling the virtues of glass, it should not be forgotten that it has the drawback of being brittle and liable to damage in use. The constant fear of breakage, both in the production environment and while in use, should not be underestimated.

Glass has, however, the ability to be used and closed with practically any type of material as the closure medium: there are no materials that can come near to its versatility with high melting points (the ability to sterilise a product in situ) and its high strength (stronger that steel, if not damaged). Although glass is basically made up of naturally occurring materials, it is capable of constant recycling without loss of its properties. Glass can be claimed to be one of the best materials, environmentally to be used for packaging. Glass can be reused (for different products, or even the same products used in the glass container); recycled (no detriment to the new materials properties); reduced (with lightweighting of containers and moulding methods the weight of the glass can be reduced) and recovered (where the recycling operation reduces the energy requirement compared to that for new glass).

Although glass is the oldest of the modern packaging materials, it is by no means the one that should come last on the technologist's list of packaging material considerations. It should be remembered that new developments are constantly emerging and that the technologist and the marketing professionals should not dismiss glass as an outdated medium. Glass is long lasting, yes, but not outdated. Glass, like many of the other forms of packaging, has different properties depending on the make-up and the constituents, but many of the basic properties remain the same and give the technologist the performance that is desired. Despite the introduction of new materials in the plastics field, glass still remains the material of choice for most of the major products in the field of luxury cosmetics and toiletries.

5 Composite containers

Victor Spong

5.1 Introduction

The term '*composite*' was originally applied to paperboard tubes fitted with metal ends that were developed to compete with lever lid metal tins. In the European Waste Regulations, the term is applied to any mixed material having no single component being more than 85% of the composition. In this chapter, we shall adhere to the more common understanding of paperboard containers having metal or plastic ends and fitments, irrespective of final composition.

The chapter will cover two types of widely used containers that are constructed from paperboard and that have plastic or metal parts, namely the square- and rectangular-shaped cartons (both gable top and brick), used principally for liquids, and the round tube and drum, produced by convolute or spiral wind techniques and predominantly used for dry products.

The carton systems have a closed, integrated form/fill/seal machine as a principal component of container making, which is extremely compact. This imparts many cost advantages, but the very limited filling space makes it unsuitable for many dry products, especially if there is a likelihood of dust. Such products are suited to the more extended layouts employed for round drums, where forming, filling and sealing are well separated. Each type of composite container will be reviewed in terms of container making, filling and closing, before the chapter moves on to a discussion of materials used and shelf life, with information on sealing techniques included, where appropriate. Finally, the author addresses environmental issues concerning the recycling and recovery of composite containers.

5.2 Gable top cartons

5.2.1 Introduction

Gable top cartons made from waxed paperboard were developed in the 1930s in the United States and Germany to replace glass bottles for the packaging of fresh milk. Large volumes of these cartons are still produced around the world, but typically these cartons now use paperboard coated on both sides with polyethylene instead of wax. The original cartons had square cross section and this is still the standard format. In Northern Europe, a rectangular section has been introduced for 1.5-litre and 2-litre cartons to fit into European domestic refrigerators (Fig. 5.1).

Figure 5.1 Gable top and brick cartons.

Gable top cartons are used around the world for a wide range of liquid products including milk, juice, detergents and short-life liquid foods; the pack has found some application even for the packaging of breakfast cereals, although this pack type has not yet been widely adopted for dry foods because of problems with filling, closing and opening.

The pack owes much of its success to the compact design of the integrated form/fill/seal machines, which allow pack speeds of up to 200 per minute for a floor space of less than 10 m^2. There is a range of equipment available, from low-speed, low-cost simple fillers through to high-speed, high-technology machines. This, coupled with low-cost containers, gave gable top cartons a strong position in the liquid packaging market until challenged by integrated plastic bottle lines.

In response to retailer criticism in some markets, the traditional gable top has been modified by folding the top down to make it flat to improve distribution. However, this created a problem at the consumer's end, as this made the packs more difficult to open, and thus caused an uptake of consumer interest in plastic bottles, for the fresh milk market at least. One innovative response to making a flat-topped, but easy-to-open, pack was the introduction of the 'Tetra Top' carton by Tetrapak. This carton comprised a paperboard body and base made from a roll of coated board; the carton was then filled and an injection-moulded top welded on to close the pack. The forming, moulding, filling, and top welding could thus all be performed on one machine.

In Europe and the United States, the paperboard carton pack has largely been replaced in its traditional fresh milk market by plastic bottles, especially for pack volumes of 1 litre and over. However, the use of original gable top pack continues for the packing of premium products such as fresh juice, drinking yoghurt and premium milks, because of its established image for premium fresh products.

The cost-effectiveness of the paperboard pack ensures its place as a serious contender for the packing of liquid food products.

The cartons are made from solid bleached sulphite (SBS) board, coated on each side with low-density polyethylene, but having a thicker layer on the inside, compared with the outside layer (usually in a ratio of 2:1) (Fig. 5.2). The board is made from virgin fibre because it can be in direct contact with liquid food products, and water-based products in particular will penetrate into the board over time. The function of the board is to impart rigidity and strength to the carton, whilst the polyethylene provides both water-resistant and heat-sealing qualities. Since the international market volumes are high, and specifications are standardised, both the polyethylene-coated board and barrier board are available directly from board mills, based in the United States and Scandinavia, rather than being coated by the converter. The more specialised alufoil laminates are usually produced by a specialist converter.

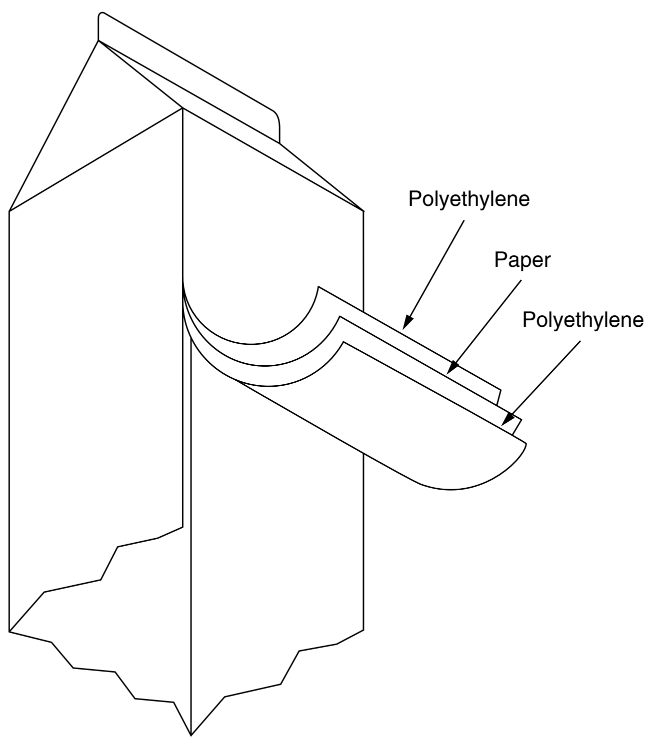


Figure 5.2 Gable top carton – carton layers.

5.2.2 Container making/sleeve production

The carton is created from the coated board through a two-stage process. In the first stage, a printed carton sleeve is made by a converter and then shipped to the filling site; in the second stage, it is erected and filled on a specialist machine by the filler/packer.

Thus, in the first stage, a roll of two-side polyethylene-coated board is printed by a flexographic or rotogravure process (see Fig. 5.3 (1)) and cut into blanks, with creases in the position of the eventual folds of the carton (2). Gable top formats are standardised, with 90% of the international market using two cross-section formats: 70 mm × 70 mm (1-litre size) and 95 mm × 95 mm (US half gallon size). This has led to the development of specialist flexographic printing presses that print and produce the blanks as a single in-line operation.

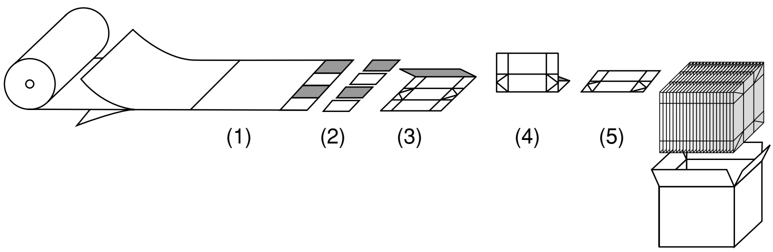


Figure 5.3 Gable top carton – sleeve production.

The carton blank is fed into a flame sealing machine, where it is folded to make a sleeve by welding the overlap of inner and outer polyethylene edges to form an inside-to-outside lap seam. To do this, the carton blanks are moved along a high speed track, where the outer surface of one edge of the blank and the inner surface of the other edge are heated using direct heat from a gas burner. These two surfaces of polyethylene are pressed together between a series of steel rollers while they cool and solidify, thus making the longitudinal seam.

The control of line speed and distance from the flame determines the heat input to the surface, which, in turn, will affect the viscosity of the liquid polyethylene and the effectiveness of the seal formed. Too little heat will give a low level of flow, with intermittent seals, whilst too much will cause the polyethylene to flow away from the seal area, reducing the amount of plastic available to form the seal and, thus, its strength.

The system is designed to produce a secure leak-proof container for cartons for liquids with a shelf life up to 28 days. The standard lap seal leaves a raw edge of the board on the inside of the carton exposed to the product, and although the board has wet-strength characteristics, these cannot be relied on beyond 4 weeks. If shelf life is to be extended beyond this, the side seal system needs to be changed such that there is no contact between the product and the paperboard. A fin seal is formed using a technique known as ‘skive and hem’. In such a case, an inside-to-inside polyethylene seal is formed by heating the two inside edges, pressing them together and folding them down (hemming). This action increases sleeve thickness at the seam from two to four layers, but may cause a problem for top sealing. To minimise the latter, the outer surface of one edge has half its board removed (skiving): this is done before the seal action, and hence the term ‘skive and hem’ (Fig. 5.4).

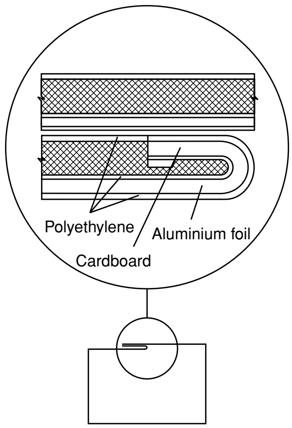


Figure 5.4 Gable top cartons – ‘skive and hem’ seam.

Crystallinity of the polyethylene will take place over the next few days as the sleeve cools to ambient temperature and is stored; it will be completed during the time that cartons are delivered to the filler. (The sleeves are shipped in a flat from the converter to the filler/packer.)

5.2.3 Base closure

In the second stage of this process, the carton is created from the sleeve at the filling site.

The sleeve is loaded onto a magazine to be fed onto a water-cooled stainless steel mandrel (6) as illustrated in Fig. 5.5. The internal surface of the base area of the carton sleeve is heated by hot air (300°C) to melt the polyethylene surfaces (7), which are then brought together and tucked in to form a gusset (as shown in Fig. 5.6). This is folded down by metal ‘fingers’ whilst the front panel edge is tucked behind the edge of the rear panel by a ski plate, the whole being pressed firmly against the base of the mandrel, which thus cools and solidifies the polyethylene, forming inside-to-outside seals (see Box 5.1).

Pneumatic pressure is used on the bottom of the carton to achieve consistent base seals. ‘Dams’ are built into the base pad to apply extra pressure to potential leak

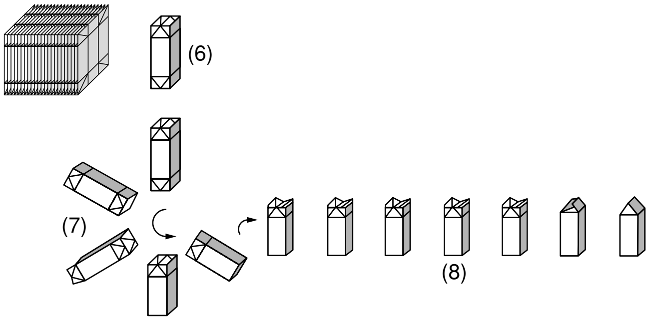


Figure 5.5 Gable top carton – forming, filling and sealing.

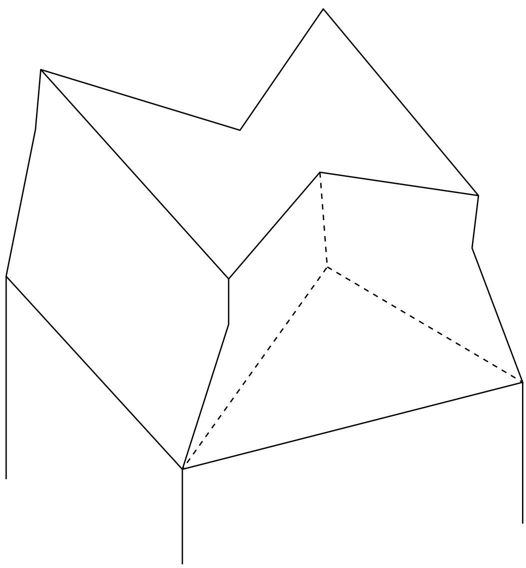


Figure 5.6 Gable top carton – top seal gusset forming.

paths. The bottom seal is often produced in two steps, with a low-pressure step to put the folds in place, and a high-pressure step to ensure good polyethylene flow and create the final seal as the polyethylene cools and solidifies. It is important to get a good heat flow to ensure even melting of the polyethylene. To achieve this, the hot air channels are designed to apply direct heat in a selective pattern on the inside of the carton to ensure heating in the areas of the folds. Likewise, a good water flow is necessary inside the mandrels to provide consistent cooling. The temperature of the mandrels must be controlled to avoid condensation; more advanced machines have captive water systems with temperature controllers, rather than taking the water

Box 5.1: Hot air sealing

Hot air sealing is used for both bottom and top seals for gable cartons, for the bottom seals of some brick cartons and for many convolute containers.

Hot air is directed at the surface to be sealed and does not have to penetrate the board layer. Thus, we can be assured that the first layer to be affected is the critical seal-forming layer. In this way, heat control is more sensitive in not having to be adjusted to compensate for board characteristics.

The polyethylene layer is heated by hot air to produce a low-viscosity liquid layer, and the surfaces are brought together under pressure and cooled rapidly to re-solidify the polyethylene. During the melt phase, the polyethylene will flow to fill any gaps and create a continuous layer. The board layer provides a non-thermoplastic backing to support the polyethylene during the molten phase.

The temperature of the hot air used is in the range 250–400°C. Older equipment uses gas heating systems for the air, but more modern machines have electric heating for better temperature control.

The quality of air used is important – it must be free from dirt and oil. Cooling is effected by pressing the heated part against a cold plate.

directly from mains. Any inconsistencies of the base seals will give rise to leaking packs.

The basic system leaves an exposed edge of the board at the apex of the folded sides and at the inside edge of the gable fold and, as with the side seam, will rely on the wet strength of the board for its life. For extended shelf life, the pattern of the base seal has to be modified, as well as the longitudinal seal (Section 5.2.2), to ensure inside-to-inside sealing with no exposed edges of paperboard. This is achieved by changing the folding pattern and shape of the blanks.

5.2.4 Fill

The container thus formed is transferred to a pocket chain; this carries the carton under a fill head, which dispenses the liquid product (see Fig. 5.5 (8)). It is important during filling that the product does not interfere with the top seals. Fortunately, gable top cartons have large headspaces and can tolerate a degree of abuse. There are, however, three issues that have to be controlled: *drip*, *surge* and *foam*.

(i) Drips from the fill head can interfere with seals; a combination of good fill head design, to take advantage of the surface tension of the product, and the product flow control will help to eliminate the problem. Fill heads can be interchanged, and different heads may be used for different products.
(ii) Surge is created by the intermittent motion of the pocket chain carrier as it moves the carton from the mandrel, stops under the fill head and progresses

on to the top seal unit, the product will move backwards and forwards up the carton. This movement can be reduced by carefully controlling the acceleration and deceleration of the pocket chain to avoid jerking.

(iii) Foam is generated when liquids having low viscosity and high surface tension (such as skimmed milk and fruit juice) are filled at speed. There are a number of means deployed to avoid the problem:

- The fill could be slowed down either by slowing the machine, or by using two-shot filling.
- Consideration may be given to the fill head design, as this is important in reducing problems and heads are often designed with particular liquids in mind, taking into account viscosity, solids content and shear characteristics. A screen system can direct the liquid to the sides of the carton rather than directly to the bottom, reducing splash back and agitation.
- 'Bottom up fill' is used on some machines. In such cases, the fill tube is lowered into the carton and raised as the product flows, reducing the impact of the product into the carton. The drawback is that it complicates the fill station and adds to cost, and there is also the danger of the product overtaking the fill head, leading to overflow and possible product contamination being transferred from one carton to the next fill.

5.2.5 Top closure

To close the carton, the inside of the top is heated, again using hot air in a pattern.

The carton side 'ears' are tucked inside, forming a gusset, and pressed together by water-cooled steel jaws. A two-step process may be used to improve the security of the seals, and the jaws are shaped to fit the contours of the multi-fold tuck and reduce the chance of any product seepage. The resultant top seal profile has a thickness variation ranging from four layers of board on the outer edges to two layers in the middle. The sealing jaws are shaped to accommodate the variation and provide liquid-tight seals. However, this process cannot be relied upon for gas tightness, and this is one reason why the system is not suited to long-life products. The top seal jaws can incorporate an embossing unit for date and production codes. The unit cannot produce the amount of information available from an inkjet coder, but on the other hand, it does have the advantage that it cannot be altered once embossed.

5.2.6 Materials

5.2.6.1 Board

The weight and strength of the board used are critical factors for achieving good-quality folding, and thus enabling good geometry and minimising stress on the seals. Moreover, there has to be sufficient strength to support the weight of contents, which can vary from 100 g to 5 kg, through the distribution and use chain. Board is normally made from virgin fibre and includes a wet-strength agent to prevent collapse during life.

5.2.6.2 Polyethylene

The polyethylene coating has two functions: it provides product resistance and allows heat sealing both inside to inside and inside to outside. The distribution of polyethylene is carefully controlled and is divided in a ratio of 2:1 between the inner and outer surfaces. An increase in the weight of the polyethylene, especially on the inside, will increase the strength of the seals – useful for demanding distribution systems. Food grade extrusion low-density polyethylene is used for liquid foods and a stress-crack-resistant grade for the packing of detergents. Corona arc or chemical treatments are used to improve printability, although it is important to avoid any contamination of the inside polyethylene that will interfere with its sealing properties.

5.2.6.3 Barrier

Products that are sensitive to oxygen or light will also need barrier materials using a layer of alufoil or barrier plastic (ethylene vinyl alcohol (EvOH) or Nylon) in the laminate to extend shelf life. More aggressive products, including orange juice containing peel oil, may call for further improvements, especially in the use of alufoil/board laminate or barrier board and improved adhesion of the internal polyethylene layer to the alufoil. A ‘tie’ layer between the alufoil and polyethylene may need to be included, often incorporating an ionomer. New products should always be tested for any interaction between product and packaging material for the planned life of the pack.

5.2.7 Shelf life

Because of the internal tuck of the seal forming the gable top, it is very difficult to guarantee the top seal for gas tightness, so the pack has to be restricted to limited shelf life applications. The shelf life of these packs can be extended using a number of enhancements. The gas barrier of the pack can be improved by using either a board having an alufoil layer or a barrier board, which incorporates a layer of EvOH or Nylon. Product resistance can be improved by using a ’skive and hem’ longitudinal seal and modified base seal.

Bacterial contamination of the product can be slowed down by improving the hygiene of both product and package. The hygiene of the filling machine can be improved by

- Sterilising the forming mandrels with a cleaning agent such as alcohol
- Creating a clean filling environment using a high-efficiency particulate air (HEPA) filter to the incoming air and lamina flow through the fill area
- Cleaning the inside of the cartons using hydrogen peroxide spray, which may be further activated by UV light

The contamination level of the product can be reduced by additional heat treatment – sometimes called ultra-pasteurisation. Shelf life may be further extended by using higher barrier cartons. These measures have been shown to increase the life of the pack, from 14 days to over 45 days for dairy products, as long as the storage temperature is maintained below 6°C.

5.2.8 Easy-open fitments

The operability and re-close of gable top cartons have become major issues for consumers, especially in Europe. These issues have been among the major factors in the replacement of cartons by polyethylene bottles for products such as fresh milk. In response, the main carton producers have developed a number of plastic fitments to allow easy opening, pouring and re-close. These fitments have added complexity and are expensive compared to the cost of the carton; they have moved the container system away from its low-cost base. Yet, they have failed to defend the carton against the polyethylene bottle in the packaging of commodity products in many markets, but have, it must be said, found use with premium products (Fig. 5.7).

Figure 5.7 Gable top carton with fitment.

An open/re-close fitment made from high-density polyethylene or polypropylene can be added to one of the faces of the gable top; this will be applied on the outside, using a hot melt, which can be designed for any fitment material. However, an outside attachment such as this is vulnerable to being knocked or pulled off during transit or use; it can be protected using a full outer board case, but this will add further to cost. A more secure method is to place the fitment from the inside through a pre-punched hole and secure by ultrasonic welding (qv), a method that is suitable only if the fitment is also made from a compatible material such as polyethylene (Fig. 5.8).

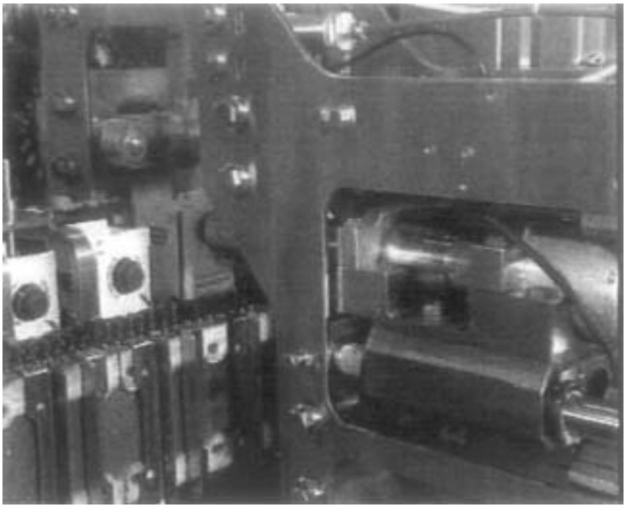


Figure 5.8 Gable top carton – ultrasonic sealing of fitment.

The design of the fitment is also restricted by the geometry of the gable; it is undesirable for the fitment to project beyond the limits of the carton 'envelope' (see also Box 5.2).

Box 5.2: Hot melt adhesive

Hot melt adhesives are thermoplastic complexes that are formulated to specific applications.

They are applied to the surface of the adherend at a much higher temperature than the melting point of the adhesive complex, producing a low-viscosity fluid that wets the adherend surface. The parts are clamped and the thermoplastic adhesive cools and resolidifies, forming a bond between the two substrates. The flow of the adhesive can fill in any irregularities, to provide a good contact.

Hot melt adhesives are also good for adhering dissimilar polymers and so they can be used for adhering fitments made from high-density polyethylene or even polypropylene to the outer surface of the carton which is of course low-density polyethylene. Hot melts adhesives using ethylene vinyl acetate copolymers are particularly useful in bonding polyethylene surfaces since they can be formulated to wet the surface and to bond at temperatures below the melting point of the fitment polymer thus avoiding any thermal distortion which is critical to ensuring the proper function of the fitment. They have good hot tack properties to assist locating and holding the fitment in place during applicatior.

Hot melt adhesives are convenient and can be applied rapidly to keep up with filling and closing machine speeds. The system is designed to have high shear strength to avoid the fitment becoming detached during transit or use.

Application systems are inexpensive. The system is well suited to applying easy-open tops to the outside surface of cartons, thus avoiding any interference with the inner surface. This is especially suited to applying tops to aseptic cartons where the integrity of the inner layer is important.

Hot melt system will also help to provide peel seals for diaphragms on convolute containers, since the lateral shear force for opening can be designed into the system. Since they are not solvent based, they are non-toxic and there is no problem with contamination of the filling room atmosphere or of any penetration of solvent into the carton.

5.3 Brick-shaped cartons

5.3.1 Introduction

Two technical drawbacks of the gable top cartons are, firstly, the gable uses space and does not stack well; secondly, there are issues apropos the reliability of the top seal for long-life products. The solution to both of these arrived with the development of the brick-shaped carton (Fig. 5.1). The pack is often used for fresh milk, but has found its real potential in the aseptic packing of liquids such as milk, juice and sauces for ambient long-life storage. The huge growth of aseptic packaging for liquid foods, especially in Europe and Asia, has been associated with the development of the brick carton – the latter is still the dominant pack for these products worldwide because of its cost-effectiveness and reliability. Brick-shaped cartons are not used for dry products because of the difficulties in accommodating filling within the small space available on the form/fill machine.

The first system for the production of this type of pack was the *Tetra Brik* carton, developed in the 1960s; this produces a brick-shaped carton from the reel. This system was followed 10 years later by *Combibloc*, in which the pack is formed from a pre-made sleeve. Both systems use two-side polyethylene-coated board for their fresh milk applications, and a laminate of polyethylene/board/ polyethylene/alufoil/polyethylene for their aseptic systems.

One recent development has been the introduction of cartons having a square section. This has been done to allow market segmentation by using the premium association of the square-based carton to distinguish premium products from basic products. Such cartons will incorporate easy-open/re-close fitments, as is exemplified below.

This laminate is produced on multi-headed extrusion coater/laminator in one pass by the converter (Fig. 5.9). A tie layer of ionomer resin may be included between the alufoil and the inner polyethylene layer to improve adhesion and resistance to aggressive products, such as essential oils.

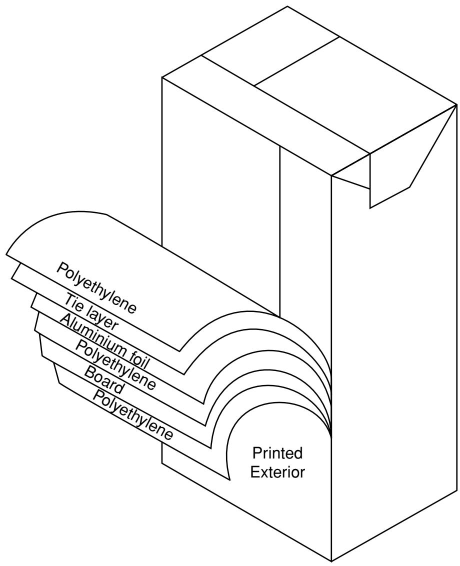


Figure 5.9 Brick carton – carton layers.

5.3.2 Reel fed (Tetra Brik)

This system was first introduced as a tetrahedron pack in Sweden in the 1950s for the packaging of fresh milk; it was converted to the brick shape some 15 years later. It is, essentially, a vertical form/fill operation, which produces a pillow pack filled with product, followed by a box-making station. The paperboard on the reel is first printed and passed through the coater/laminator. The print is sandwiched between board and the outer polyethylene to protect it from the sterilising liquid used on the forming and filling machine. The reels are slit down to widths appropriate for the filling machine and shipped to the packer/filler for forming and filling.

5.3.2.1 Reel fed pack – pack forming

At the forming/filling machine, the reel of laminate is unwound, a strip of polyethylene is attached to one edge and the web is passed through a bath of hydrogen peroxide sterilant. Squeeze rollers remove surplus hydrogen peroxide before the web passes through a creasing station where the carton brick shape creases are embossed. It then moves to a forming ring, where it is formed into a tube. Hot air is applied to activate the peroxide and dry the web to remove any residual peroxide. Residual peroxide will cause oxidation of the product and, in the United States, the Food and Drugs Administration regulations also impose a 0.1-ppm limit to residual peroxide. Thereafter, the pack is enclosed in a sterile zone with sterile air. The sterile web passes down the forming tube; as it continues down, a lap seal of inside-to-outside polyethylene is made to complete the formation of a tube for the product. The polyethylene is activated by a longitudinal heating bar, which seals the polyethylene onto the outer polyethylene surface of the coated board over the join. However, since the lap seal will leave an exposed edge of board to the product contact surface, this area is over-sealed with an extra strip of polyethylene (Fig. 5.10).

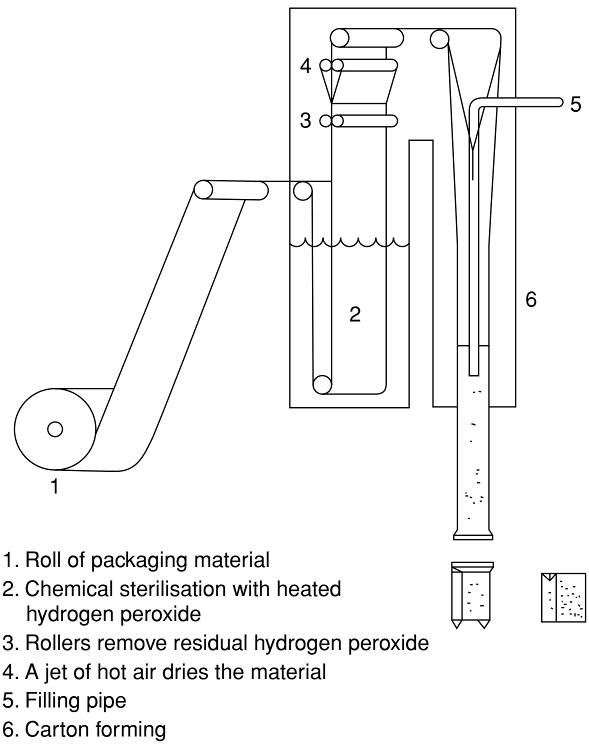


Figure 5.10 Brick carton – reel fed.

5.3.2.2 Reel fed cartons – filling and closing

The product filler tube is located inside the forming tube and discharges the product in time with the movement of the web. This allows a column of product to lie above the base seal; the bottom seal jaws come in and clamp the laminate web through the product column, drawing it down to the required pack length. These jaws are made as a double set: the upper set forming the bottom seal of the upper pack, and the lower set forming the top seal of the lower pack. As the web is clamped together, these seals are made, using induction or ultrasonic welding, to melt the inner polyethylene layer. The resultant seal has no gussets and, therefore, there is no risk of microbial re-contamination and a very low gas transmission rate. As the jaws draw down, they hold the web together whilst cooling takes place and the polyethylene re-solidifies.

The seals are made through the product column, thus eliminating any headspace. This sealing technique will cope with low-viscosity liquids; the filling of highly viscous liquids, or liquids with pieces, requires a modification to the system. Similarly, if headspace is required, it is created by injecting a sterile gas into the product line. The small increase in thickness at the longitudinal lap seal is accommodated by shaping the sealing jaws to fit. Where induction sealing is used, the alufoil layer of the laminate web provides the element to activate the heat into the polyethylene and forms a strong paper-tearing weld at high speed. The packs are separated by a knife cutting through the web at the bottom of the draw stroke. The output from this section of the machine is the well-known pillow pack shape associated with vertical form/fill seal (VFFS) machines, with the product enclosed inside.

5.3.2.3 Reel fed – pack shaping

As the packs are cut and separated, they are transferred into a pocket wheel to form the familiar brick shape using the crease lines to help re-shape the pillow pack. The top ‘ears’ are folded down the carton side whilst the bottom ‘ears’ are tucked into the base of the carton (see Box 5.3).

Box 5.3: Induction sealing

Induction welding is a type of electromagnetic welding which uses induction heating from a high-frequency (0.1kHz to 10MHz) alternating current to magnetically excite electromagnetic particles embedded in a bonding agent at the interface of two parts being welded. The heat released is used to melt and fuse thermoplastic materials. It is a reliable and rapid technique which results in strong welds.

In the case of brick cartons, the induction welding of the inner polyethylene uses heat generated in the aluminium foil layer being transmitted to the polyethylene. The polyethylene melts and flows together under pressure from the jaws. The weld takes less than 0.5 seconds to complete and results in a high-quality stress free joint that is pressure tight. The weld is held together whilst the polyethylene resolidifies.

Integrity of seals is most important in aseptic applications, since not only must the liquid be retained but also the seal must be gastight to minimise oxygen transmission and prevent recontamination of the aseptic pack by bacteria.

5.3.3 *Sleeve-fed system (Combibloc)*

The principle of this system is similar to that of the gable top (Section 5.2), whereby sleeves are produced by the converter and subsequently shipped to the filler/packer to be erected and filled. Starting with the polyethylene/board/ polyethylene/alufoil/polyethylene web produced on the extrusion coater/laminator, the pack is made in two stages (in some ways similar to that for gable top cartons), namely sleeve production and pack forming and filling.

5.3.3.1 *Sleeve production*

The extruder reel is initially surface printed using the flexographic or rotogravure process. It is then passed through a cutter creaser where the carton blanks are made. (These have the crease lines for the final brick carton embossed into the board.) The rectangular blank is then put through a flame sealing operation to create the longitudinal seal. As with the gable top cartons, direct heat from a gas burner is used to melt the edges of the blank. For long-life cartons, it is important that there is no product contact in the filled pack; consequently, an inside-to-inside fin seal is formed using the 'skiving and hemming' technique (see Section 5.2.2 and Fig. 5.4).

In the same way it is important to control the line speed and distance from the flame to achieve effective sealing. Once completely cooled, the seal will have an indefinite life.

Crystallinity of the polyethylene weld will take place as the sleeve cools to ambient temperature and stands over the next few days, and will be completed during the time that cartons are delivered to the filler. The carton sleeves are shipped in boxes to the filling site for stage two, where the carton is created (Fig. 5.11).

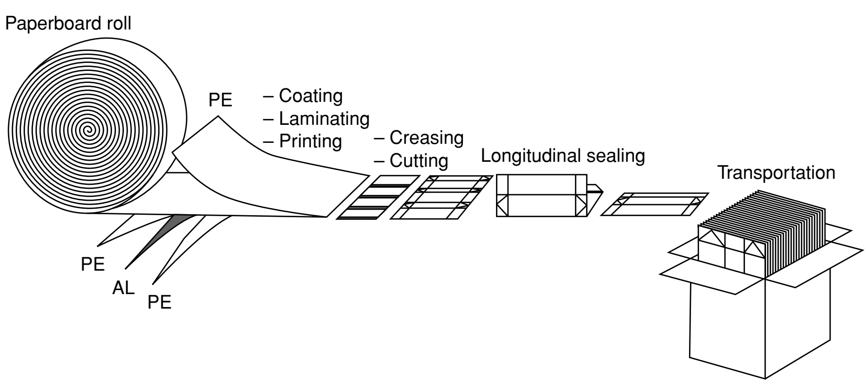


Figure 5.11 Brick carton – sleeve production.

5.3.3.2 Sleeve fed – pack forming and base closing

At the filling plant, the sleeve is loaded into a magazine to be fed onto a water-cooled alloy mandrel. The internal base area of the carton sleeve is heated by hot air (300°C) to melt the polyethylene surfaces, which are brought together with the side walls tucked in to form a gusset with inside-to-inside contact. The gusset is folded down and pressed firmly under high pressure against the base of the mandrel, which then cools and solidifies the polyethylene. There is no interlocking of the back and front edges, as with gable top cartons, so there will be no exposed edge of the board laminate (Fig. 5.12).

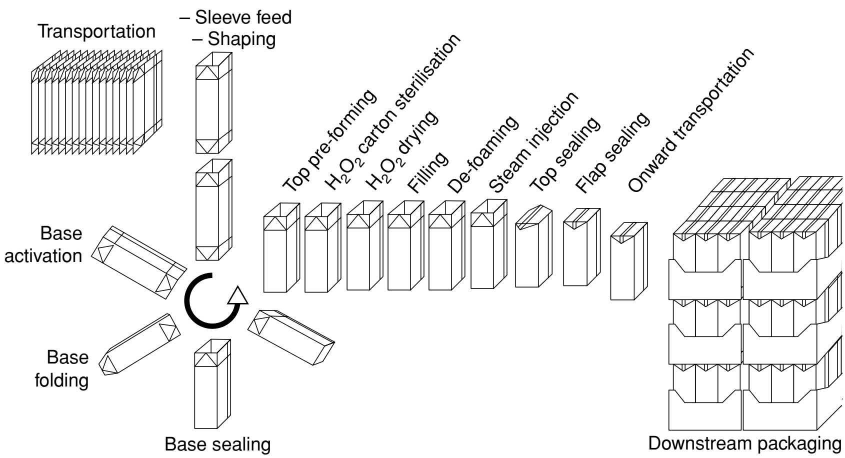


Figure 5.12 Brick carton – forming and filling.

Pneumatic pressure is used on the bottom of the carton to achieve consistent base seals, and the mandrel is hollowed out to allow for the folds of the paper layers and to provide a stable base. It is important to get a good heat flow to ensure even melting of the polyethylene. To achieve this, the hot air channels are designed to direct heat in a selective pattern on the inside of the carton to ensure heating in the areas of the folds. Likewise, a good water flow is necessary inside the mandrels to provide consistent cooling, although the temperature of the mandrels should not be so low as to encourage condensation. Inconsistencies of the base seals can give rise to leaking packs.

This system does not leave an exposed edge of the board on the inside against the product; all product contact surfaces are polyethylene. The seals are tight, giving good barrier to gas and bacteria, at the same time creating a stable base. Once the base has been completed, the open-top container, thus created, is transferred to a pocket chain to carry it through the filler. The carton moves into the sterile zone and passes under a spray of hydrogen peroxide vapour to sterilise the inner surfaces. Hot sterile air is applied to activate the peroxide and remove any residue. Before arriving at the fill station, the residual peroxide must be below 0.1 ppm to meet US Food and Drug Administration standards; excess residual peroxide can oxidise the product. The sterile zone is maintained by a laminar flow of filtered sterile air.

5.3.3.3 Sleeve fed – filling

The sterile carton then moves on inside the sterile zone to the fill station, where aseptically processed liquid product is filled using a volumetric cylinder or flow meter. Since the filling takes place into the carton from above, it is important that the product does not interfere with the top seals. Brick-shaped cartons have much smaller headspaces than those of the gable top cartons, and so a more controlled fill is needed. Thus, drip, surge and foam are potentially more serious issues. Drips from the fill head can interfere with seals, although only if the product has high viscosity or particles, since the ultrasonic system will be effective through low-viscosity liquids. However, even these drips may give an unsightly appearance to the carton, and should be avoided. A combination of good fill head design to take advantage of the surface tension, viscosity and shear of the product, together with product flow control, will help to eliminate the problem. When the filled carton is moved along in the pocket chain from the fill head and stopped under the top seal unit, the product will surge backwards and forwards up the carton. This movement is reduced by carefully controlling the acceleration and deceleration of the pocket chain to avoid jerking. The filling machines are of multi-lane design to minimise cycle time and acceleration whilst maximising output.

Many liquids, especially those having low viscosity and high surface tension, are liable to foam during filling. There are a number of means deployed to avoid the problem as discussed in Section 5.2.4:

(1) The fill could be slowed down further, by filling the product in two stages, with half the product being filled at the first stage and half at the second.
(2) Fill head design can reduce problems, and filler heads are often designed with particular liquids in mind, taking into account viscosity, solids content and shear characteristics.
(3) A de-foamer can be used. This is a metal pipe attached to a suction pump which is positioned just above the fill level and removes foam to the container.
(4) Product flow meters provide better control of the product fill, reducing fast entry into the container and adjusting flow speed to fill level.

Bottom up fill is not acceptable for aseptic filling, because of the risk of contamination from one pack to the next.

5.3.3.4 Sleeve fed – top closure

To close the carton, metal ‘fingers’ enter the top of the carton to draw the top edge to a straight line. The top is now sealed using ultrasonic welding, whereby a horn presses the top seal area against an anvil and the high-frequency vibrations generate heat between the horn and the anvil, thus causing the polyethylene at the interface of the two sides to melt and flow together (Fig 5.13 and Box 5.4).

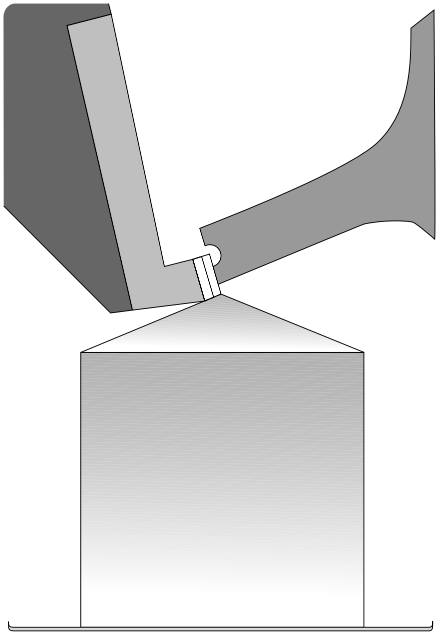


Figure 5.13 Brick carton – ultrasonic top seal.

Box 5.4: Ultra sonic sealing

Ultrasonic welding is the most commonly used technique in plastic welding. It is a process where high-frequency vibrations are transmitted via an acoustic tool (horn) to the parts to be welded.

It utilises ultrasonic energy at high-frequency ranges beyond the range of human hearing – (20–40 kHz) to produce low-amplitude mechanical vibrations. The vibrations generate heat at the joint interface of the parts being welded, resulting in melting of the thermoplastic and weld formation after cooling. Internal and external absorption of the mechanical vibration causes the plastic in the joint area to heat up until it reaches its melting point. The mechanical pressure applied simultaneously causes a molten pool to be generated and the two parts to merge. When the material cools down a virtually homogenous joint is formed. Ultrasonic welding is the fastest known sealing technique with weld time of about 0.5 seconds. Components used for ultrasonic sealing are a generator (power supply), a converter, a booster and a horn or sonotrode.

In Fig. 5.14, the *power supply* (1) transforms the energy supplied by the mains electricity at a frequency of 50 Hz to an ultrasonic frequency of 20 kHz. The high frequency oscillations of the power supply (I) are transformed by the *converter* (2) into mechanical vibrations (S) of the same frequency, i.e. 20 kHz using a piezoelectric oscillator. These mechanical vibrations are transmitted to the polyethylene coating, using an acoustic tool consisting of a *booster* (3) and *horn* (4).

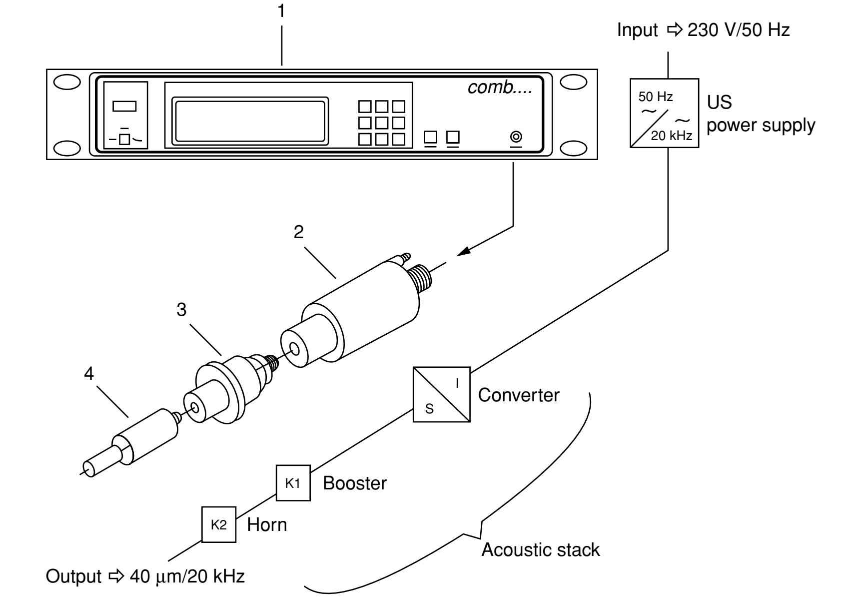


Figure 5.14 Components of an ultrasonic system.

The two sides are held together after the welding has taken place to allow cooling and solidifying of the polyethylene before the pack moves on. The profile of the horn is shaped to allow for the small thickness variation at the longitudinal seam. The resultant seal is almost completely linear and flat, giving low gas transmission rates and microbial barrier to prevent re-contamination of the sterile pack.

5.3.4 Brick shape carton materials

5.3.4.1 Paperboard

The function of the board layer is to provide stiffness and mechanical strength to the pack. The basis weight is therefore specified according to the anticipated product weight, which may range from 100 g to 2 kg. Although having similar strength requirements, both reel-fed and sleeve-fed systems have different stiffness requirements: the reel-fed system requires a flexible board to conform to shaping around the forming collar, whilst the sleeve system requires a stiffer material to stand well in the filler pockets. Some recycled board is now used for long-life packs, given that for aseptic packs, no contact is allowed between product and board during the life of the pack.

5.3.4.2 Polyethylene

The distribution of polyethylene is carefully controlled and divided in a ratio of 1:2 between the outer and inner surfaces. Normally, food grade extrusion low-density polyethylene is used. Many long-life products have aggressive ingredients (such as acids and essentials oils) that will penetrate the polyethylene layer and delaminate from the alufoil layer. To overcome this, a tie layer incorporating an ionomer may be used.

It is important that new products are thoroughly tested for any interaction between the product and the carton, and the test result should be capable of being extrapolated through to the designed life of the pack. In practice, these reactions usually become apparent in weeks rather than months. New laminate materials, in which the alufoil layer is replaced by a barrier polymer, are being introduced (as with gable top cartons – see Section 5.2.6). These can provide adequate gas barrier at a lower cost and are useful where lower shelf life is acceptable, such as with high turnover products.

5.3.5 Shelf life

Long-life liquid foods usually deteriorate in two ways: the first and fastest method is by microbiological action. Low acid foods such as milk will be affected principally by bacteria, whilst high acid products, such as juices, will be affected first by yeast and moulds. The fundamental principal of aseptic processing and packaging is to eliminate microbial contaminants before, and during, filling and prevent re-contamination after filling. If this is achieved, then the pack will last indefinitely – there is no such thing as semi-aseptic. Failure of the pack seals is a major cause of pack loss through spoilage as a result of re-contamination. Seal quality, therefore, becomes one of the critical control points of the system, and rapid test methods for seal quality have been developed to allow at-machine quality control of seals.

Once pack integrity has been achieved, the next issue will be that of chemical breakdown. Most foods will deteriorate by oxidation, using oxygen trapped within the product, introduced into the pack during filling or entering the pack over time. This oxidation will be promoted by UV light, and so the aluminium foil layer has a double function of providing a high barrier to gas – gas will enter through the seals rather than through the body of the pack – as well as a barrier to light.

It is this oxidation process that often determines the shelf life of the pack, since, as long as there is no re-contamination, sterility will be maintained indefinitely. Aseptic packs have shelf lives from 6 months to 2 years whilst sealed, depending usually on their susceptibility to oxidation or other chemical reactions, such as by enzymes. Once opened, the packs have a 3–4 day life under refrigerated conditions.

5.3.6 Easy-open/re-close fitments

Brick-shaped cartons have been designed to be fully sealed with no paths for gas and microorganisms. However, this can actually contribute to difficulties for consumers in opening them. The first attempted solution to this problem was to introduce lines of weakness by perforating the board layer by the carton ears. This, however, did not ameliorate the problem sufficiently for many consumers and provided no re-close. Hence, the development of easy-open and re-close fitments has been a major area of activity by the carton system producers (Fig. 5.15).

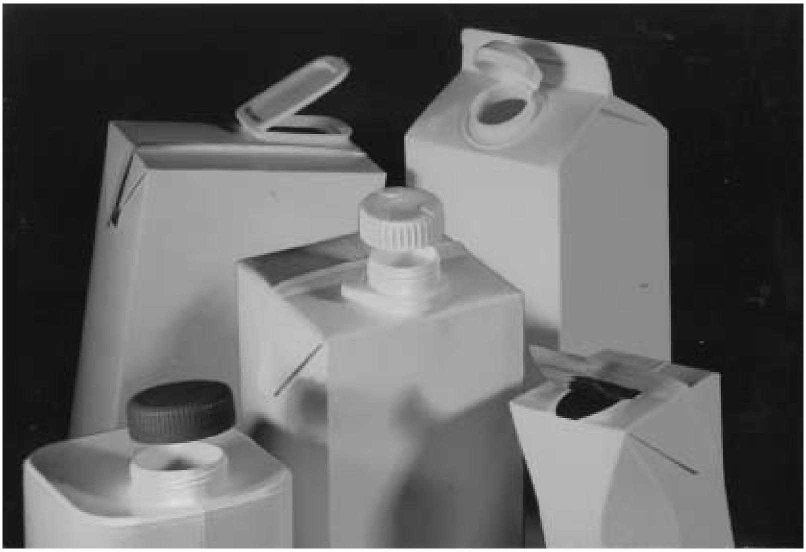


Figure 5.15 Liquid carton fitments.

The first series of fitments were designed to lie flat and have a lift lid which clicks back into place. There are two main approaches to such fitments nowadays: the *Tetra* system (Recap) has a pre-punched hole which is sealed with a tab of alufoil/polyethylene to maintain sterility; a high-density polyethylene fitment is positioned over the hole and sealed in place with hot melt adhesive. At the point of opening, the lid is lifted to expose the tab which is then peeled back to open the punched hole; the lid is replaced to re-close the pack for storage.

The *Combibloc* system (CombiTop) relies on perforating the board layer at the top of the carton. The fitment is located over the perforation, again using hot melt adhesive. At the point of opening, the lid is lifted, and a tongue of plastic pushed down through the perforated carton top and locks in place, creating an aperture. The fitment is designed with a pour spout and the lid clicks back into place after dispensing for storage.

Both designs of fitment are flat for ease of storing and transport and are secured to the outside of the carton using a hot melt adhesive. There has been a reluctance to introduce screw cap designs because they stand superior of the pack and complicate stacking and secondary packaging. However, in response to consumer demand, screw caps have now been introduced. Figure 5.16 shows the spin cap designed by *Tetra Pak*, in which the initial rotating action of the cap lowers a cutting tool

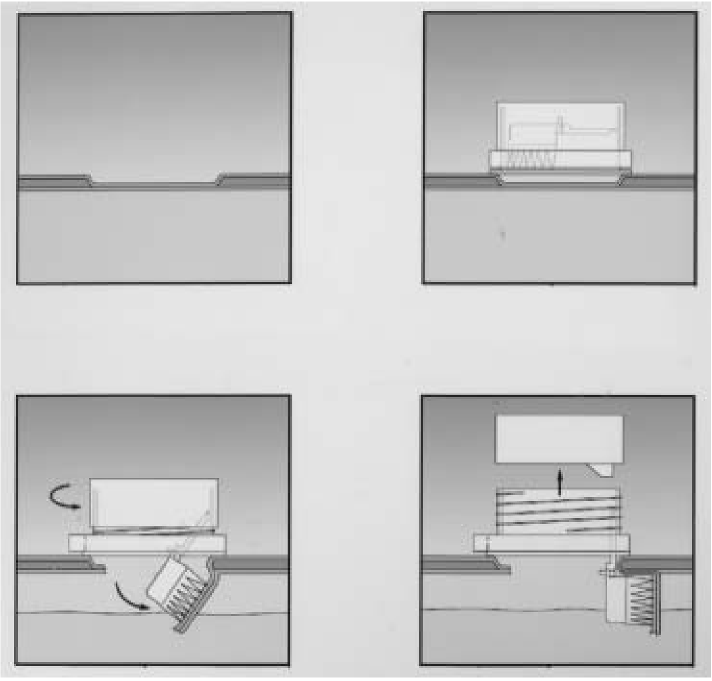


Figure 5.16 Tetra Pak – spin cap.

through the alufoil/polylayer and locks open; thereafter, the screw top acts to open and re-close for normal use.

As with gable top cartons, these fitments introduce a significant cost increase to the pack and are used for the premium product variants. Indubitably, this will be an area for continuing development as designers try to optimise cost and ease of use.

5.4 Aseptic filling

5.4.1 The aseptic process

Aseptic filling is an integral part of the aseptic processing and packaging of liquid foods for ambient long-term storage (Fig. 5.17). In this chapter, it will be discussed only with reference to brick cartons.

The aseptic process sterilises the food product by heat, but unlike conventional in-pack sterilising used in the canning process, it does so in a more discreet and gentle manner. The conventional in-pack sterilising process involves filling the product into the container, closing it hermetically and passing it through a steriliser, which heats the container under high-pressure steam for a time of up to 40 minutes, depending

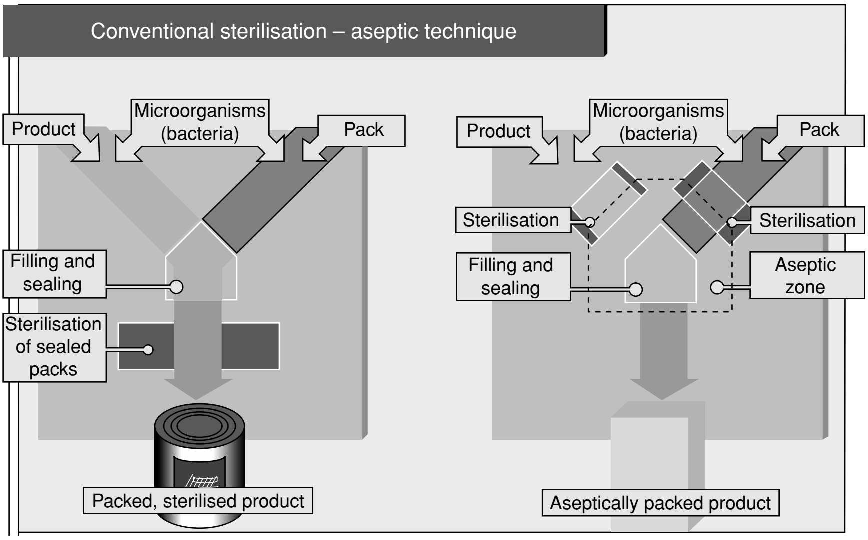


Figure 5.17 Aseptic versus conventional canning.

on the size of the pack and viscosity of the product. The result is that the food is subjected to large amounts of heat to ensure that the product at the centre is fully heated; this can affect nutrients, flavour and colour. Moreover, the container has to be robust enough to withstand the heat process. The process is however very reliable, well understood and easily controlled.

Aseptic processing, also known as HTST (high temperature short time), on the other hand, requires close control of all functions to give optimum results. The product is sterilised in a continuous flow process that applies heat required to sterilise only the product, without concern for the ultimate pack size. The package is sterilised separately using a chemical sterilant. The product and pack are kept in a sterile state to prevent re-contamination and are then brought together again in a sterile filling area before the pack is sealed.

In Fig. 5.18, the curves represent the time/temperature curves for aseptic and conventional canning. The area under the curves represents the heat input to the pack and shows the difference between the processes.

The aseptic system applies much less heat to the product and, therefore, will cause less heat damage (and consequently will have a less deleterious effect on colour, flavour and nutrients). This makes the system ideal for vitamin-rich products, such as milk-based drinks and fruit juices, as well as for heat-sensitive products, such as sauces. It is less suitable for meat-based products, where a slow cook is required for texture.

The most commercially successful applications have been for low-viscosity liquids, such as milk and fruit juice, which have high market volumes. Not only is the sterilising process more gentle on the liquid food, but the chemical sterilising of the

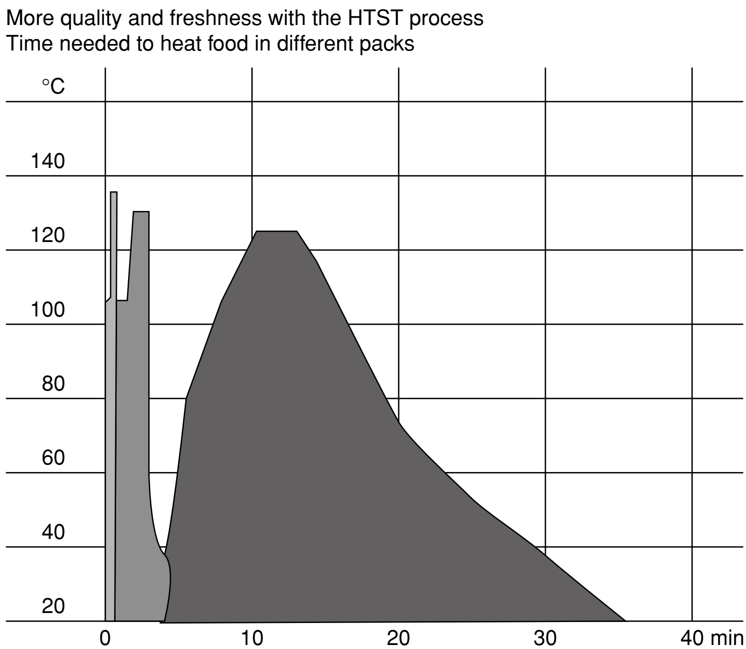


Figure 5.18 Aseptic processing – heat inputs.

pack puts less strain on the container. This means that lighter weight packaging can be used, and this is one reason why the system is well suited to paperboard cartons and light-weight plastic containers: the continuous sterilising and filling process will produce high volumes of packed product at low cost.

5.4.2 Sterility

Sterilisation of both product (by heat) and the package (by chemicals) is a killing process that follows a logarithmic function, such that absolute sterility is never achieved. What is sought is commercial sterility, so that any microorganisms that survive will cause neither a deterioration of the food, nor a pathenogenic action to humans. Commercial sterility is defined as

- The absence of disease-causing microorganisms
- The absence of toxic substances
- The absence of microorganisms capable of multiplying under normal conditions of storage and distribution

During the ultrahigh temperature (UHT) process for milk, spores are allowed to survive, as long as there is no multiplication. The heat sterilising process normally seeks to achieve a log 12 reduction in microorganisms, whist the packaging sterilisation will achieve a minimum of log 5 or 1 per 100 000 packs: the difference reflects the potential contamination levels for each. The actual failure rate of packs will depend on a number of factors including

- Hygiene regime of the plant
- Contamination level of the packaging material or product

5.4.3 Aseptic packaging

There are three key operations in aseptic packaging: sterilisation of the packaging material; creation of a sterile environment during filling; and the production of a pack with hermetic seals to protect commercial sterility by preventing re-infection.

5.4.3.1 Sterilisation of packaging material

The first commercial aseptic system was the Dole canning system – a few of which are still in use today, where a metal can is sterilised by superheated steam prior to filling. This has been largely replaced by systems that use chemical sterilising agents – either hydrogen peroxide or oxonia (peracetic acid). Both systems work through a fast oxidation process. Chemical systems impose less physical stress on the container, and so lighter packaging material, such as coated paperboard cartons or light-weight plastic, can be used.

Although peracetic acid is still favoured in many plastic bottle plants, hydrogen peroxide is favoured for carton systems because of its speed of action and ease of removal. It also has the benefit of being unstable and converting rapidly to oxygen and water. The US Food and Drug Administration, in approving the use of hydrogen peroxide, called for a minimum peroxide concentration of 30% to be used with a maximum residual of 0.1 ppm. In achieving an efficient sterilising effect, it is important that the sterilant is able to act on the complete inner surface of the container and then to be completely dispersed. The inside of the pack should avoid pockets where microorganisms can lodge without being touched by the sterilant.

In the *Tetra* system, this is achieved by carrying the whole web through a bath of hydrogen peroxide, squeezing out the excess and then inserting a heating element at the point of tube formation to activate and remove any residual. The *Combibloc* system relies on injecting hydrogen peroxide vapour into the pack, followed by high temperature sterile air, which activates the peroxide and removes any residue.

5.4.3.2 Creation of sterile environment

All areas of the fill station have to be sterile to prevent contamination during filling. Product contact parts, such as the fill head, must be capable of being both cleaned by *Clean in Place* (CIP) regimes, using solutions such as caustic soda and acid washes, and sterilised by steam or hot water. The parts are, therefore, made from high-grade stainless steel. Even non-contact parts are cleaned by chemicals, including detergents and alcohol, and must also be made from stainless steel or alloy materials. The internal surfaces of the filler must be designed to be smooth and free from voids where the product may be trapped. Sterility of the area is usually maintained after cleaning, by using a laminar flow of sterile air.

5.4.3.3 Production of hermetic closures

It is important to ensure hermetic seals to prevent re-contamination. These seals must be complete welds, with no discontinuities that will allow bacteria and/or oxygen to penetrate. They must also be strong enough to withstand handling during normal use. Aseptic carton systems achieve this in two ways:

- They ensure that the two opposite faces of the top seal are completely flat – i.e. with no gussets. The resulting 'ears' are then folded outwards down the side of the formed carton.
- They use high-speed sealing techniques such as induction or, increasingly, ultrasonic. These techniques give very strong and reliable seals at high speeds.

Any easy-open fitment systems are applied externally using hot melt adhesive systems. A continuous membrane is preserved between the fitment and the product until the moment of opening.

5.5 Round containers – convolute

5.5.1 Convolute production

The convolute process is suited to the production of a range of shapes and sizes to give a bespoke container. It can produce containers that are circular or oval, straight sided or tapered, and can accommodate lower output volumes more easily than does the spiral wind system. Convolute tubes/drums are formed by the converter and shipped to the packer/filler for filling and closing. The body and base is made from a blank, which is then supplied to an intermittent motion forming mandrel in a similar way as that for a gable top carton (see Section 5.2) and using similar materials. The main difference is that the container is made of three pieces instead of one: the body, the base and the top, each being separate. Although the bases are made from the same material as the body, the top is normally a membrane diaphragm which can be varied according to use and shelf life requirements. A plastic overcap is applied to protect the diaphragm.

The containers are made at speeds similar to the filling speed, and each container-making machine is set individually so that linking container making to filling is feasible. Changing the profile is not, however, possible. The technology was originally developed for vending cups – now largely replaced by plastic – hence, the polyethylene-coated board material often being referred to as 'cup stock'. The tapered shape cannot be produced by the spiral wound system (see Section 5.6) but can be produced only on an individual mandrel system.

Tapered containers are still used for ice cream, especially for premium varieties, because of the superior graphics of the paperboard material. More recently, the tapered cup shape in larger formats has found a new market for snacks and confectionery, what is known as the ‘cinema pack’ and a bulk party pack. The taper delivers two benefits:

(1) Reduced cost of shipping the empty containers, since they can be nested
(2) Ease of use especially for scooping and dipping

Straight-sided convolute containers are more expensive to ship empty, since ‘nesting’ is not possible. The development of new volume markets for snacks and biscuits has been made possible by co-locating the container production with the filling operation to reduce shipping costs. The storage of empty containers can still be an issue for the packer/filler. The straight-sided containers can provide better barriers to moisture vapour and gas and are used for more demanding applications; they are also more space efficient than tapered packs for storage and shipping after filling.

5.5.1.1 Production of blanks

In the most common system, rolls of two-side polyethylene-coated board (or coated alufoil/board) are printed and cut into blanks for the body; unprinted rolls of similar specification are used to produce pre-cut discs for the base. It is important to ensure that the print does not interfere with the polyethylene coating areas used for heat sealing. The coating is usually of low-density polyethylene, although other materials may be used with adhesives (Fig. 5.19).

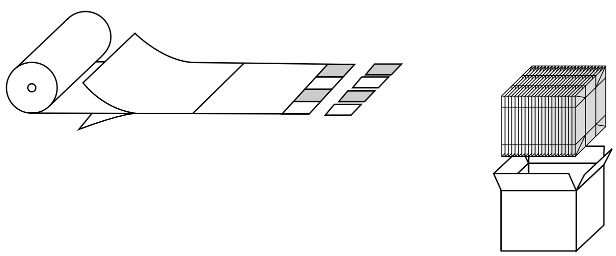


Figure 5.19 Convolute containers – blank production.

The convolute container is made from the blanks and discs in two steps on a machine having two interconnected rotating turrets: the first to form the container and the second to rim the top.

5.5.1.2 Container making and base closure

In the first step, base discs and container blanks are fed from magazines to the first turret with its set of mandrels.

The discs are first fed onto the erecting machine (Fig. 5.20 (#3)); they are then heated by hot air onto the polyethylene layer and applied to the forming mandrel, where they are held. The mandrel moves round to receive a blank (#1, #2), which is wrapped round the base disc and mandrel (#4) (Fig. 5.21). The base area of the blank is heated, again using hot air, whilst the lap seam forming the side seam of the container is also heated by direct plate.

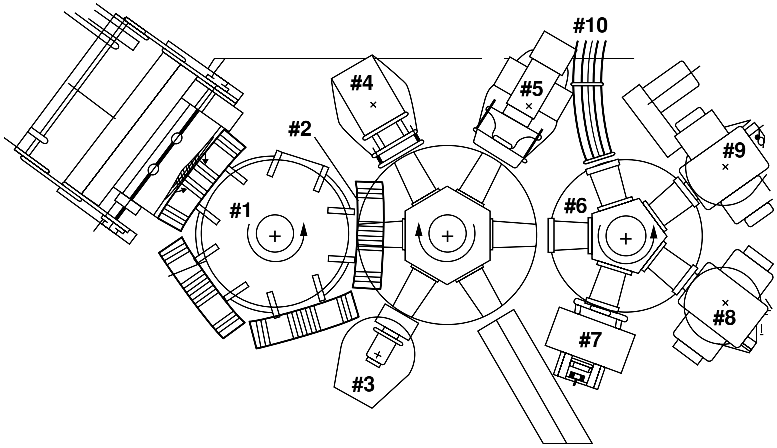


Figure 5.20 Convolutes – container making.

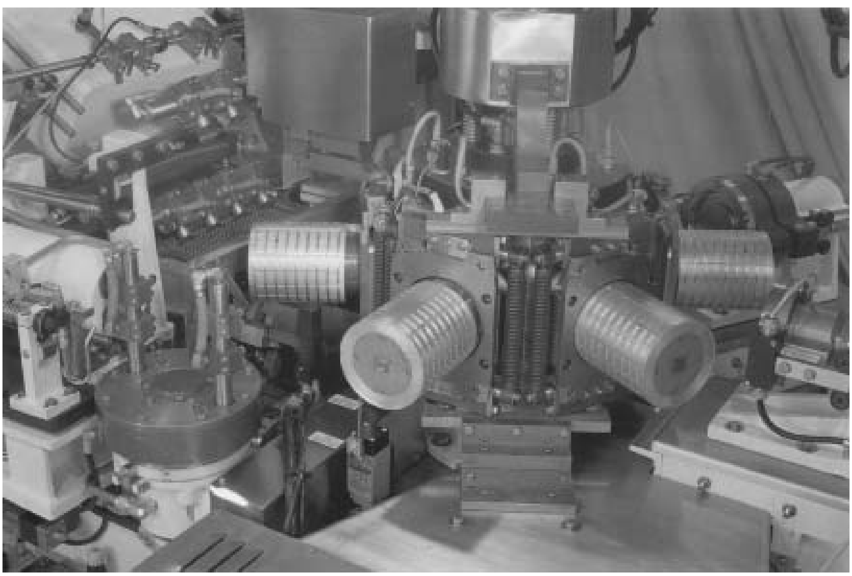


Figure 5.21 Convolutes – a round mandrel.

The heated overlap surfaces of the blank are pressed together to create the longitudinal side seam. At the same time, the base disc and blank are crimped together (#5), allowing the two polyethylene interfaces to melt together to form a join and, when cooled, a rimmed base. Figures 5.22 and 5.27 show the formation of the recessed base.

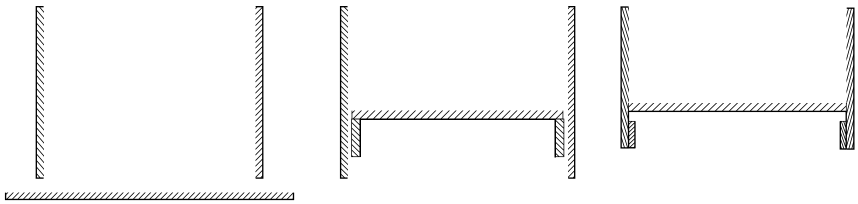


Figure 5.22 Convolutes – recessed base.

The rimming not only creates a leak-proof bottom but also forms a strong stable base.

5.5.1.3 Top rim

The formed container is ejected from its mandrel and transferred to a second mandrel mounted on another turret (Fig. 5.20 (#6)). This machine forms the top roll by warming the top edge of the container and then rolling it over to form the rimmed top (#7, #8, #9). This roll top offers an upper edge of the inner polyethylene layer of the container body suitable for applying a heat seal membrane. The thickness of the roll top will depend on the ultimate method of top sealing; a thick roll is required for an outward bead diaphragm (see Fig. 5.23), whilst a simple fold over will be sufficient for a recessed diaphragm.

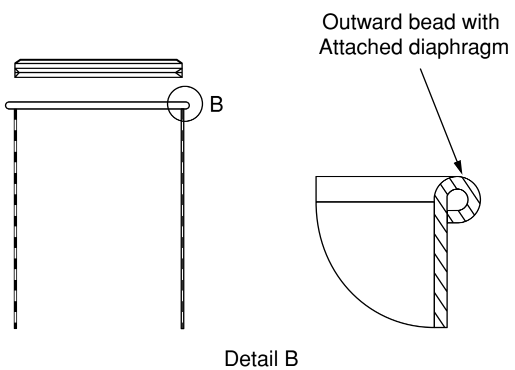


Figure 5.23 Convolute – outward bead diaphragm.

The roll top has a number of functions:

- It protects the container top edge
- It forms a hoop to give increased side strength
- It presents heat sealing surfaces to allow for the application of a membrane

The container can now be removed and transferred to a filling machine. The intermittent nature of the container forming gives outputs that may be quite close to filling speeds. Thus, depending on machine utilisation, it may be economical to locate the container-making unit at, or close to, the filling plant, to eliminate costly transport of empty containers and improve inventory.

5.5.2 Top closure

After filling, the container is normally sealed using a heat seal membrane applied to the top rim (see Fig. 5.23). This provides both tamper evidence and a barrier to moisture vapour. The membrane comprises a heat-stable web (paper, polyester or aluminium alufoil) coated with a thermoplastic coating (usually low-density polyethylene or hot melt) supplied on a roll; the web is unwound from the roll and passes over the top of a container and under a heated plate; the plate is brought down and presses the membrane onto the top rim to heat and melt the thermoplastic coating. At the same time, a knife system is used to cut out the shape of the container in the membrane web (a tear/pull tab extension may be allowed for).

If a non-weld seal, such as a peel seal is desired, then the membrane coating can be designed for this, either by modifying the polyethylene used, or by using a hot melt coating. Direct plate heating is the most common system for forming the seal (see Box 5.5). With this method, a steel plate is heated and simply pressed down on the join. The temperature is adjusted to allow for heat to pass through the membrane support layer and melt the polyethylene coating of both the membrane and the top rim of the container. Induction or ultrasonic sealing can be used but both are much more expensive. The container may be moved forward to a cooling plate or even

Box 5.5: Direct heat welding

Variants of direct heat systems akin to ***hot air sealing*** (see above) are extensively used in the closing of composite containers, as these containers are increasingly made using board coated on one or both sides with low density polyethylene or linear low-density polyethylene. During the construction of the container, the heater can be applied directly to the sealing interface. In the case of bottom seal forming in the many applications above, the hot air is directed at the surface to be sealed and does not have to penetrate the board layer. Thus, we can be assured that the first layer to be affected is the critical seal-forming layer.

Hot air systems are fast, inexpensive and simple, avoiding the need for adhesive. However, they are applicable only where the sealing surface is available to be heated directly and suffer from a lack of the precision that is available from other methods, especially ultrasonic and induction.

It is important to keep the press tools clean. There can be a build-up of polyethylene during extended operations and this will cause seal problems with seals being pulled apart again whilst still soft.

allowed to air cool. The speed of fill gives enough sealing time to allow for this. The use of induction sealing is an option, but at slow sealing speeds, the advantage is lost against the much higher cost of equipment. Finally, a plastic cap is placed over the membrane to provide mechanical protection during storage and transit and a re-close facility during use once the membrane is removed.

5.5.3 Filling

Convolute containers are used for both liquid and dry products. Liquid products, such as icecream or drinks, present the same issues of drip and slop as liquid filling of cartons (see Sections 5.2 and 5.3). The dry products filled into these containers are most commonly discreet pieces, such as chocolate confectionery, wrapped candy, popcorn, cookies and snacks. For these, volumetric or weigh pan systems are the most suitable, and problems of interference with seals are rare. Where a more demanding product is to be packed, specialised filling equipment can be fitted to the line. This equipment is usually specified by the packer/filler. Since the filling operation is separate from the container making, there is a lot of scope for designing product-specific fill stations. More space means that multiple fill heads and vibrating belts can be employed.

5.5.4 Materials

The method of manufacture of convolute containers is closely related to that of gable top cartons (Section 5.2), i.e. it is based on a heat sealed mandrel formed body. The considerations regarding materials are similar. The basic material is a polyethylene-coated SBS board made by the same mills as those that supply the liquid boards. Added shelf life is realised by using barrier boards incorporating alufoil or barrier polymers for the body, and barrier materials in the top diaphragm. If aggressive products, such as those containing spice oils, are to be packed, a 'tie' layer will be needed between the sealing layer and the barrier polymer or alufoil.

5.6 Round containers – spiral tubes

5.6.1 Introduction

The 'composite can' is the generic name for a spirally wound paperboard tube with a metal disc seamed onto the base. It is considered a strong durable pack designed to keep the product both fresh and protected, this type of container has been long established in the market where it replaced the lever lid tin. Traditionally, it was used for powders, such as household cleaners, dry foods and DIY products. It has also found wide use as a protective pack for high-value bottles, such as whiskey. Although many household applications have been taken over by plastic bottles, with their superior resistance to water, tubes have found new uses for snacks, confectionery and biscuits.

The process is a continuous production of a tube, which is cut into lengths to make circular drum packs, followed by application of either top or base. The process is high speed and is suited to high volumes of a limited number of diameters. The tube itself is essentially a low-cost unit but has higher cost end pieces.

As with convolute containers, a spiral wind container has three components: the tube body and two end pieces. The tube itself has three layers, namely, an inner layer of coated paper or a paper/alufoil laminate; a middle layer constructed from two or three plies of recycled paperboard; and an outer label, normally of printed paper. A base and a lid are applied to the tube, either of which can be made from metal, paperboard or plastic.

5.6.2 Container making and materials

A spiral wind tube obtains its strength from the efficient use of materials of construction in discreet layers each giving specific properties. Each layer of material is supplied to the forming machine on a roll of precise width. The material is taken off the roll and passed over an adhesive roller – normally water based – which is used to bind it to the next layer, before going round the barrel. The barrel constantly rotates and the material webs are drawn along to create the spiral effect; the diameter of the barrel determines the diameter of the container (see Fig. 5.24).

The inner layer provides barrier protection for the product; for instance, a grease barrier to prevent the contents staining the tube, or a gas barrier to prevent oxidation of the contents. Typically, this will mean a layer of polyethylene-coated paper or paper/alufoil laminate. A presentation pack for bottles, on the other hand, will need

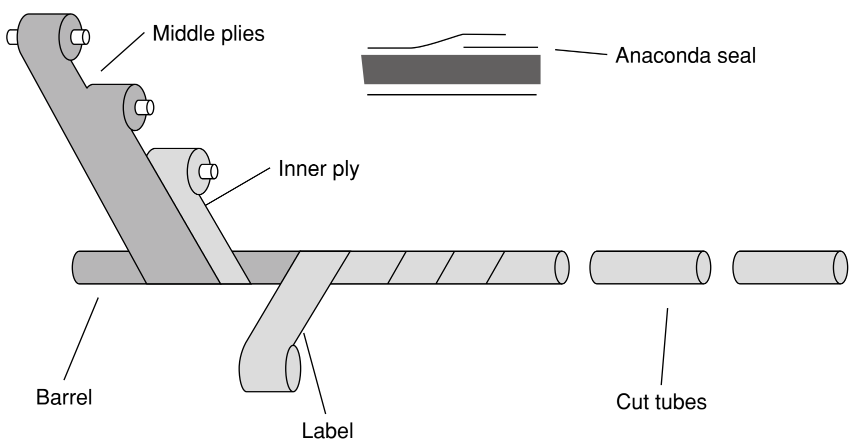


Figure 5.24 Spiral tube – tube making.

no barrier and so a plain paper lining will suffice. The middle section, comprising two or, possibly, three layers will be made from a low-cost bulk board – in general this will be recycled chipboard, although where more stiffness and strength are required, kraft-based board is used. The outer layer will be the label: a printed paper, which can be applied spirally on line or in a separate labelling operation. Which method is chosen will usually depend on run length – high volumes favour the spiral route.

Each of the layers is wound around the rotating steel mandrel, each turn abutting the next, one layer over the other, with the joins of one layer offset to the next. The layers build up on each other to form the tube, which is drawn steadily along the mandrel. The tube is cut into the required pack length. Where water-based adhesive is used, the tubes must be allowed to dry before having the ends applied.

If a barrier is required, one edge of the inner layer is turned back on itself and heat sealed to the opposite edge, as it goes round the mandrel to form what is known as an 'anaconda' seal (see detail in Fig. 5.24). This avoids presenting a raw edge of the board to the pack contents as well as creating a barrier join.

5.6.3 Top closure

Spirally wound containers are normally shipped with one end piece installed by the container maker. This is usually the most complex end. Thus, for a simple push fit end top closure, such as a bottle pack, the fitted end would be the base. For a membrane seal or recessed membrane, the container maker will fit the top. There are three common types of top seals: (i) push fit lid; (ii) outward bead diaphragm and (iii) recessed membrane.

5.6.3.1 Push fit lid

This type of lid is commonly used for bottle packs; the tube is supplied with the base fitted (see Section 5.6.4.1 and Fig. 5.26). The top edge may be left, as it comes from the mandrel, and a metal or plastic lid simply pushed on. With this type of pack, a strong body is required, and the lid made to close specifications to provide the right fit – tight enough to be secure, but capable of being opened without too much strain. A tamper-evident seal is normally applied after filling and closing.

5.6.3.2 Outward bead diaphragm

This system is similar to the top closure used for convolute containers (see Section 5.5.2). The inner lining of the tube has a coating of polyethylene on the inside surface. After removal from the mandrel, the tube has the top edge rolled outwards to form a bead edge or rim having the polyethylene-coated surface available for sealing. A diaphragm lid, again composed of paper/polyethylene or alufoil/polyethylene, is positioned across the bead and heat sealed, using direct plate heating or induction (with an alufoil layer). In addition, a pull tab extension may be incorporated into the diaphragm. The support material for the diaphragm will be either paper or paper/alufoil laminate, depending on the barrier requirements of the container. The diaphragm provides a barrier closure, preventing product leaking out and moisture vapour coming in; it also gives tamper evidence. A plastic cap is fitted over the membrane to provide protection during transport, and re-close after first opening.

5.6.3.3 Recessed membrane

The recessed diaphragm is used for high barrier applications and is normally made with alufoil/polyethylene and, thus, the inner layer of the tube is also an alufoil/polyethylene material. It has the most secure sealing system and is suitable for long shelf life packs of hygroscopic or gas-sensitive products, such as snacks. The top can be left as made, rather than rolled, since a sealing bead is not necessary. Frequently, it is folded over to give a better finish. The pre-cut alufoil/polyethylene disc is inserted into the top and crimped or heat sealed into place. Heat sealing is preferred to provide tamper evidence and better barrier to moisture vapour and gas. A tear tab is usually attached to the alufoil disc to facilitate opening (Fig. 5.25).

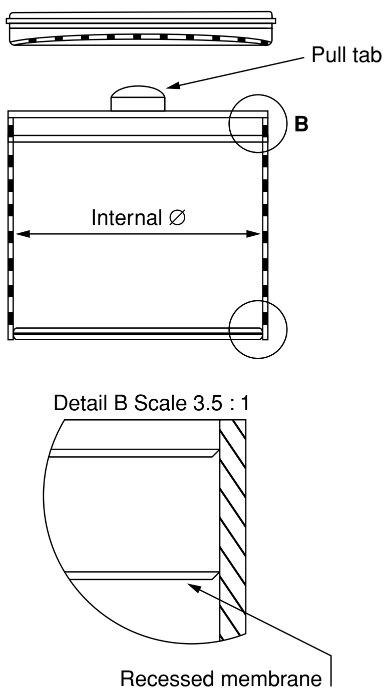


Figure 5.25 Spiral tube – recessed membrane.

Again, a plastic cap is fitted over the membrane to provide protection during transport and re-close after first opening.

5.6.4 Base closure

Except where the container has a push fit, spiral tubes are supplied with the top in place, and have the base completed after filling by the packer/filler. There are three common forms for bases:

(1) Metal seamed base
(2) Folded and sealed paperboard base
(3) Bead and insert paperboard base

Apart from serving to contain the product, the base has an important role in providing the pack with its lateral and stacking strength.

5.6.4.1 Metal seamed base

After filling through the bottom, the container is moved to a seamer where the base is secured. A metal end disc is applied to the base of the container and the edge is rolled over the edge of the paperboard tube to form a tight mechanically cleated seam. The seam is good enough to provide a good barrier to gas and moisture as well as being leak-proof (Fig. 5.26).

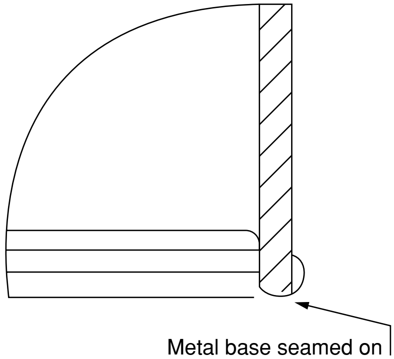


Figure 5.26 Spiral tube – metal seamed base.

5.6.4.2 Folded paper base

A paper disc is recessed into the bottom of the tube and secured in one of two ways to leave an overlap of tube material. In the first method, the inside of the tube liner has adhesive applied and it is folded over the recess edge of the base disc, thus forming a strong stable base. The disc and liner may be of uncoated board for a water-based adhesive. If greaseproof coating or polyethylene coating is used, a hot melt adhesive is required. This system is used for non-barrier applications, such as confectionery (Fig. 5.27).

In the second method, both the liner and the disc are polyethylene coated. The tube board is folded around the recessed edge of the disc as before, but without any

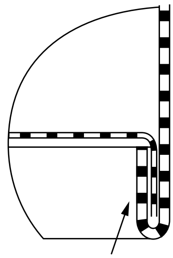


Figure 5.27 Folded paper base.

adhesive application. The rim is then heated to ensure melting of the polyethylene coatings and a full weld on cooling. This is the preferred method where a barrier is required, for example, with snacks or hygroscopic dry powders.

5.6.4.3 Bead and insert

In this process, the base disc is cut to fit the internal diameter of the tube (i.e. with no recess material) and is inserted into the base; the bottom edge of the tube is then curled round to hold the paperboard disc in place (Fig. 5.28). This base is the simplest to form, but the least secure, and is suited to products having discreet pieces and low barrier requirements, such as wrapped candy.

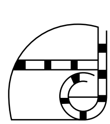


Figure 5.28 Spiral tube – paper bead and card.

5.6.5 Fill – dry products

Spiral containers are used for a wide range of dry products, from fine powders to wrapped confectionery. As with the convolute tube, the fill system used is usually the one specified by the packer/filler and designed for his product. Since filling is a discreet operation, the filler can be placed as convenient on the line. Contamination of the top seal area by the product has to be avoided, especially where long shelf life is required. Light powders particularly suffer from 'dusting', in which particles hang in the headspace of the container and may interfere with the top seal. The use of auger weighers, which precisely meter the product and deliver it inside the pack, is recommended to control the fill of the product into the pack. The problem of shake down is minimised by using multiple filling with vibration. If product contamination is inevitable, it may be necessary to increase the thickness of the inner polyethylene to encapsulate fine dust particles. For oxygen-sensitive products, an injection of inert gas before filling will purge air from the container and help in extending pack life.

5.6.6 Shelf life – dry products

Depending on the product's life cycle, shelf lives from 6 months to 2 years may be specified for dry products. Snacks and biscuits with high fat contents usually have a faster turn around and shorter product life requirement, compared with dry goods grocery. The most common source of failure for dry products is moisture. For less hygroscopic products, the barrier provided by the polyethylene-coated board may suffice. More hygroscopic products with longer shelf life requirements or more demanding environments (e.g. tropical) will require the use of moisture barrier materials such as alufoil or barrier polymers. They need to be incorporated, into both the body and the ends of the container, and a secure method of closure adopted. High fat products are sensitive to oxygen and will have similar material and closure requirements. Aggressive products will also need to have resistant materials included in the product contact surface layers. These have already been discussed under Section 5.2.6.

5.7 Environmental – recovery and recycling

Gable top cartons, brick cartons and convolute containers are made from up to 85% paperboard, using a high proportion of virgin fibre. As such, they are, in principle, a valuable material for recycling. Spiral wind containers, having a large component of recycled board, are already less valuable in the waste stream. Paperboard is produced from trees that are grown in managed forests and are a renewable resource.

Paper recycling is achieved by agitating the paper in water to form slurry, from which the fibres can be recovered, followed by a de-inking process. Paper fibres lose strength every time they are recycled, and so a quantity of virgin fibre is always needed to provide strength for a new paper or board. The polyethylene coating on composite containers is resistant to cold-water agitation, but using hot water or steam will accelerate the break-up and recovery process. The polyethylene used in the carton and fitment can be recovered by passing the slurry through a screen; this will separate the polyethylene as a film as well as any alufoil. An integrated paper and board recovery mill will be able to utilise the polyethylene recovered, as a fuel. Alufoil can be aggregated and is a valuable recoverable metal (Fig. 5.29).

The technology is readily available and in use; its application at any time is determined by economics. If virgin pulp prices are high, recovery is economic; if pulp prices are low, recovery is not viable. This business is very cyclic and leads to periodic gluts of paper for recycling. In the case of liquid boards and cup stock, the equation

Figure 5.29 Liquid cartons – recovery of components.

is further complicated by the additional cost of using hot water. Furthermore, the wet-strength agent used in these board grades will increase the time needed for complete dispersion of the paper fibres. These will to some degree offset the value of the virgin fibre available.

The recycling process is further complicated by the cost of recovering the cartons from the waste stream. The operation is easily justified when using commercial waste, with cartons and board from industrial operations being available in good condition (free from food contamination) and in reliable volumes from few locations; however, post-consumer waste is quite a different matter. Even though cartons and convolutes can be easily crushed to save space, they are lightweight packs, and carton banks yield small volumes of contaminated waste at many sites; there is also the issue of their distance from the recovery mill – this is likely to result in high transport costs. In Scandinavian countries, post-consumer waste is collected in the general waste stream and used in *Waste to Energy plants,* where the high calorific value and low ash content of the cartons is a valuable component of the mix.

In the case of spiral tubes, the situation is more difficult, since the board used in the centre bulk plies is already made from recycled material, and is therefore much less valuable. Moreover, it is not easy to distinguish the two types of round containers once made: the containers are more rigid, having both bases and tops in place after use, so they cannot be easily crushed for the domestic waste stream. Thus, they are even more costly to recover as post-consumer waste and less valuable to a recovery board mill. Again, *Waste to Energy plants* will be able to separate and recover the metal components, whilst the board provides a valuable non-fossil fuel.

5.8 Conclusion

Paperboard is a relatively cheap raw material and is made from a renewable resource: it has good mechanical strength and rigidity and can be shaped; it has good printability, using most printing techniques and is able to facilitate high-quality graphics at low cost; furthermore, the material is recyclable. The major drawback for the packaging of most products is that paperboard has no barrier to moisture or gas, and is attacked by water. As a single material, it is widely used as a collating pack: carton, sleeve or case. For other purposes, it must be combined with other materials – most commonly, heat seal polymers or barrier alufoil. In the case of composites, the body of the container is principally of low-cost paperboard, which provides the strength and rigidity of the pack. Thin layers of polyethylene, alufoil or barrier plastic are combined with the board to impart heat-sealing and barrier properties. Likewise, the end pieces will be combinations of paperboard, polymer or metal, ranging from a heavy aluminium end cap to a thin plastic diaphragm.

Composite containers were first developed between the 1920s and 1930s to replace glass or metal containers. The rise of these containers has seen the demise of the lever lid metal can for many applications and the glass bottle for fresh milk. However, composite containers themselves are now being challenged by the rise of plastic containers. The advantages of the composite container against its plastic rivals are good graphics, pack rigidity and good barrier to moisture and gas, at a lower cost. Certainly, plastic containers offer a wider range of shapes and low unit cost in circumstances where a gas barrier is not important. As the cost of barrier polymers reduces, opportunities for more sensitive products will increase.

To conclude, the future of composite containers looks bright, particularly as technological advances create more product opportunities. In addition, given the societal attitudes and pressures towards the use of renewable materials, such as paperboard, non-renewable packaging materials (such as plastics, which are derived from fossil fuels) may find that environmental issues limit their opportunities for expansion in this market.

Acknowledgements

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6 Closures for plastic bottles and tubs

Richard Larbey

6.1 Introduction

Closures for plastic bottles and tubs are available in a wide variety of design types, sizes and colours; and are capable of employing a number of different sealing systems to suit almost all filled products – be they foods or chemicals, in liquid or powder form. The selection of a closure for a given purpose should be made with as much care and attention as that given to the selection of the bottle or tub. Indeed, the sealing interface is usually the most vulnerable point of a package of any description, and judicious selection is repaid handsomely in the form of trouble-free service. Special features, such as tamper evidence, child resistance and venting, are also major considerations. The use of techniques such as life cycle analysis and failure mode and effects analysis (FMEA) are also worth considering before making a final choice of closure.

Most closures for plastic receptacles are also manufactured using plastic. The most commonly used polymers are the thermoplastics, principally high-density polyethylene (HDPE) and polypropylene (PP), although polystyrene, acrylonitrile butadiene styrene (ABS) and other copolymers are also used. Thermosetting plastics, such as urea formaldehyde, still find considerable favour due to their inherent rigidity and good appearance; however, the resulting trade-off will be lower impact resistance.

6.1.1 Plastic bottle necks

In considering closure systems and their effectiveness on plastic bottles, it is necessary to understand the methods of manufacture, since these directly influence the choice of seal. Two principal methods are used to blow-mould bottles: extrusion blow and injection blow. With extrusion-blow moulding – mainly used for high-volume HDPE bottles – the neck is formed by the blowing pin, which forms the neck internal and top surfaces, and the subsequent blowing pressure, which forces the material into the neck threads (see Fig. 6.1).

With thicker walled bottles, there is often enough material between the neck form and the blowing pin to obviate the need for the air pressure to complete the forming and make a smooth bore. Where the wall is thinner, the neck will have a narrower top section (often termed the chimney) that maintains a small area of ‘squeezed’ neck, thus preventing air from creeping into the sealing area and thereby causing leakage

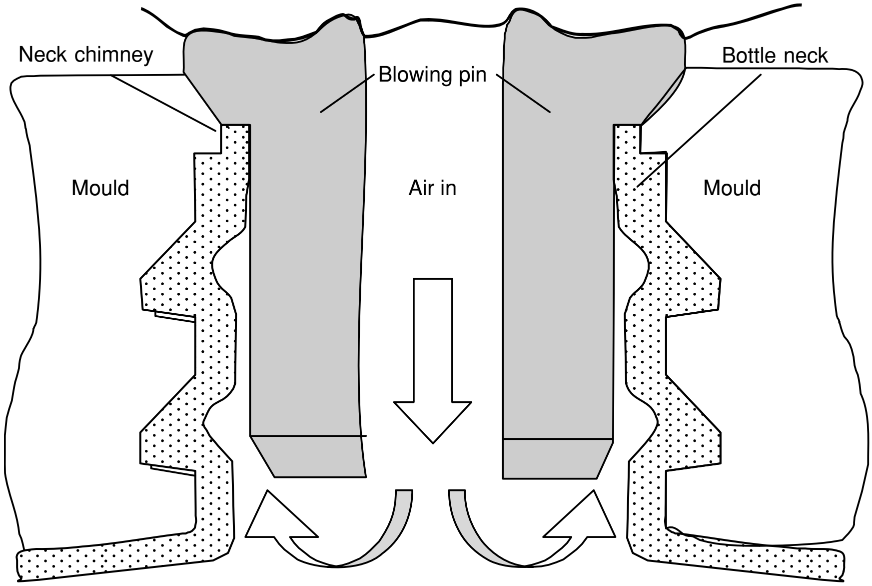


Figure 6.1 Extrusion blown neck.

with valve-type seals. Where the wall is very thin (such as with polyethylene bottles used for milk and juice), moulding a defect-free chimney requires high skills and vigilance, and therefore some manufacturers prefer to blow the neck with a top land and use a special 'pull-up' blowing pin arrangement that cuts through the land to form the bore. Whatever the type, great care is required to maintain good sealing properties.

With injection-blow moulding, mainly used for polyethylene terephthalate (PET) and also for small HDPE and PP bottles, the bottle is blown from a heated injection-moulded pre-form (Fig. 6.2) that carries the neck. Injection moulding offers much closer dimensional control, and consequently the neck is very consistent, ideal for onerous applications such as pressurised beverage containers. This begs the question: 'Why not use injection blow for *all* plastic bottles'? The answer, predictably, is cost. Most injection-blow applications are two stage (injection mould the pre-form, then insert this into a blow mould to form the bottle), which adds cost. Modern single-stage machines, where the two processes are combined, are hugely capital intensive and both systems really pay dividends only with high value-added products, such as those for personal care applications where the higher packaging cost can be justified. Bottle size is also a consideration, injection blow being somewhat limited to smaller sizes. This is a fast-moving area subject to continual development, and the best advice is to check with manufacturers. Figure 6.3 shows a selection of container necks moulded by these methods.

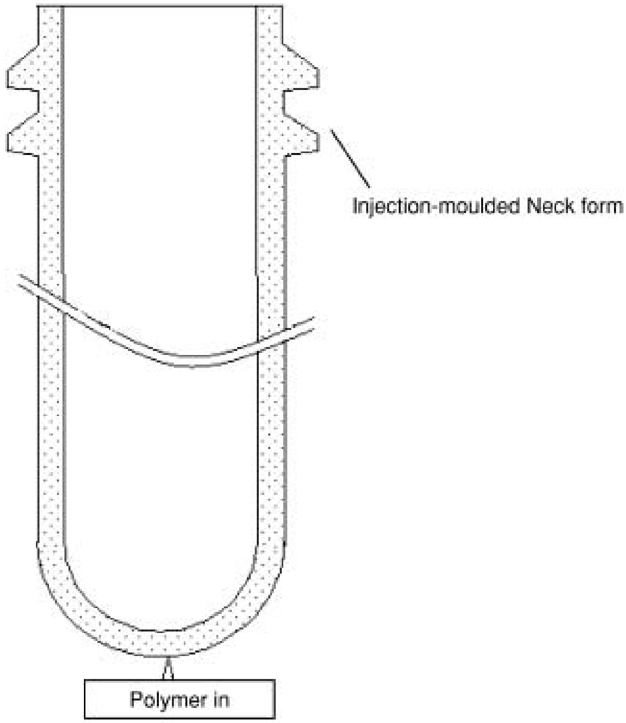


Figure 6.2 Injection moulded pre-form.

6.1.2 Plastic tub seals

Plastic tubs can be moulded by three methods: firstly, they can be extrusion-blow or injection-blow moulded, as for bottles, and carry a large-diameter closure of conventional design as discussed below. Secondly, they can be injection moulded – where hot polymer is injected into a tightly clamped mould having a cavity shaped to both inner and outer surfaces. These will usually carry a ‘press-on’ lid, especially for larger vessels such as pails and paint cans – the greater dimensional stability of injection moulding means this is the ideal method for such wide openings. Finally, they can be vacuum formed – where a thin, heated sheet of polymer is ‘pulled’ by vacuum into a cavity shaped to the external surface of the tub. This method is ideal for small, mass-produced tubs and portion packs, such as those used for yogurt, hard fats and convenience foods. These will either have a similarly moulded press-on lid, or be conduction heat sealed (where a foil/polymer peelable laminate is heat welded to the rim of the tub) for portion packs. Both methods are often used in combination for products such as hard fats – the peelable seal for longer shelf life and the replaceable lid for end-user food preservation, protection and convenience.

Figure 6.3 A selection of plastic container necks. Top – Extrusion blow-moulded, HDPE, modified buttress-threaded, angled screw neck for child-resistant closure (CRC). Centre – Injection-blow-moulded, pre-formed PET, modified buttress-threaded neck for tamper-evident capture bead sports closure. Left – Extrusion blow-moulded, spin-off trepanned wide neck with annular bead for push-on dispensing closure. Bottom – Injection-moulded, open top pail for press-on lid.

6.2 Screw closures

Undoubtedly, the most common form of providing closing force is the screw closure. The helical screw thread has several advantages; principally, its ability to multiply the down force at the sealing interfaces where leakproofness under arduous conditions, such as in export transit or over long storage periods, is critical. Conversely, however, this can lead to over-tightening of the closure, and the design of the thread form is important with plastic in which its flexible nature can lead to excessive stresses. The most common thread form is the modified buttress (Fig. 6.4), which was developed from conventional buttress forms to provide both structural strength and a free-running thread with good resistance to overriding. The form is mirrored on the bottle neck.

Other types, notably rounded thread forms, can offer both cost advantage and a faster cycling in closure manufacture, because they do not require the complex and expensive mould rack and pinion unscrewing mechanisms prior to ejection of the closures . Caution in the selection of a rounded thread form closure for a plastic bottle should be exercised, and should be limited to applications where tightening force is low and service conditions are light.

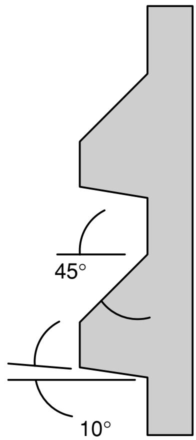


Figure 6.4 Typical modified buttress thread form.

Plastic closures are available in a wide range of sizes and designs, defying several attempts at standardisation over the years. Essentially, where the closure is a ‘fashion’ item as part of a retail pack designed to have strong visual and novelty appeal, it will be designed exclusively to form part of the overall pack. Where the economics of the packed product do not justify a bespoke pack, off-the-shelf bottles and tubs rely more heavily on readily available standard closures, of which a wide range is available from many manufacturers. Classification here is much easier and in general follows long-established rules, though there are still many pitfalls for the unwary, and it is strongly recommended that manufacturers are consulted technically on the compatibility of any given closure/container combination. Shallow closures are termed R3 and have only one full turn of thread for quick application and removal. Deeper closures are termed R4 and can have from one and a half turns up to three or even four turns. The former are popular for smaller packs, particularly for fresh milk when filled and capped on high-speed equipment and the latter for industrial uses, where the greater security of the closure is beneficial, and the greater height makes for easier gripping where hand capping is used for short runs. R3 and R4 screw closures are available in a range of diameters, from the smallest practicable for end-user comfort (approximately 12 mm) to the largest (approximately 100 mm). The classification here can be confusing, as the industry ‘standard sizes’ do not refer to any particular dimensional feature of the closure, being derived from container neck standards, and with only a loose correlation to the thread crest diameter. Thus, a 28-mm R4 closure will be 28 mm in neither external nor internal diameter. Figure 6.5 shows a selection of R3 (shallow) and R4 (deep) closures.

6.3 Sealing media

The choice of sealing medium is as important, if not more so, as the choice of the closure itself. It is recommended that a period of testing, small- and larger scale,

Figure 6.5 A selection of 'R3' and 'R4' plastic closures. Top left – 38-mm R3 shallow tamper-evident closure for HDPE fresh milk and juice bottles. Top right – 38-mm R4 deep plain closure for general and industrial use. Bottom left – 28-mm R3 shallow plain closure for general use. Bottom right – 28-mm R4 deep plain closure for general use.

culminating in full transit and storage trials be conducted prior to use. This applies even where manufacturers offer standard products for specific purposes, as the exact conditions of use through the life cycle of the product will vary, and assumption of suitability for any given purpose is inadvisable.

6.3.1 Linerless seals

These have become prevalent for closures for plastic bottles and tubs due to their lower cost and their particular effectiveness in using the flexible nature of plastic container necks to provide a good seal. With the most common linerless seal, the valve (Fig. 6.6), an angled plug is forced into the bore of the neck, both components are then relaxed by cold flow over time.

The valve design is critical, as is good dimensional control over both its diameter and that of the container internal neck bore. Modern production methods for plastic bottle necks have given a high level of dimensional consistency, which has made the valve a very reliable method of sealing. The relaxation of valve seals will however lead to some loss of 'tightness' over time, the closure appearing to be loosely fitted than when first applied. This phenomenon is sometimes erroneously referred to as 'backing off', as if the closure mysteriously unscrews itself, but is more accurately termed 'torque decay'. It is entirely normal, does not affect leak tightness and should not be treated by further tightening the closure, which can cause distortion of the sealing valve or container neck, leading to leakage. If leakage occurs from valve seals, it is more likely due to either low closure application torque or a defect in one of the sealing components. The inherent stresses imposed by the valve of a

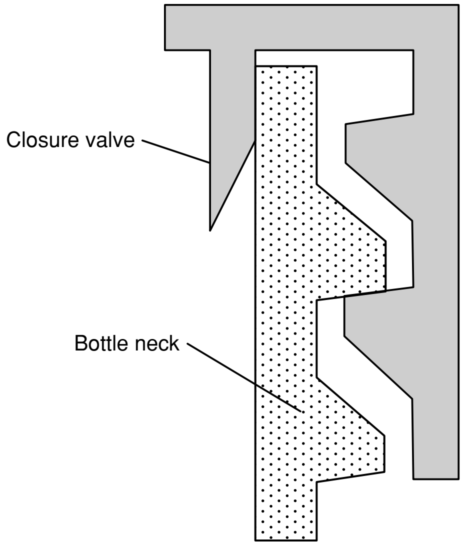


Figure 6.6 Typical valve seal closure.

thermoplastic closure into the neck of a polyethylene or polypropylene bottle can lead to the component suffering environmental stress corrosion (ESC – i.e. stress cracking), with some chemicals and preparations containing either wetting agents such as detergents and cleaning products, or strong oxidising agents. The risk is exacerbated by higher ambient temperature. The choice of closure and container polymer can reduce this risk, but in extreme cases the use of a valve seal may not be possible, a liner being preferable.

The valve can also be used to fit over a pre-fitted spout in the neck, such that when the closure is removed, the spout is pulled into its extended position. This feature is especially common for lubricating oils.

One variation on the valve seal is the ‘crab’s claw’ (Fig. 6.7) where a flexible flange of that sectional shape rests against either the top surface, the bore or outer wall of the container neck.

This type of valve seal is suited to viscous or powder products in less arduous applications, or is used as a secondary seal to the main valve. Another is the ‘v-seal’ (Fig. 6.8), a much smaller yet robust annular feature in the top of the closure, sometimes in multiples, which seals against the top surface of the neck, which must be accurately moulded to achieve a good seal. Finally, the crudest form of linerless seal is the flat land, where the container neck and cap simply meet in flat contact. Such a seal is not recommended for liquids, yet is ideal for coarse powders and tablets where air tightness is not critical or where a heat-sealed membrane is employed as the primary medium. Figure 6.9 shows a selection of linerless seal closures.

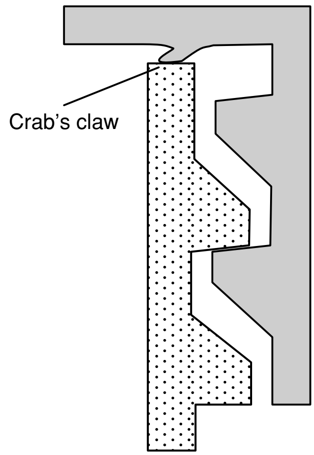


Figure 6.7 Typical 'crab's claw' type seal.

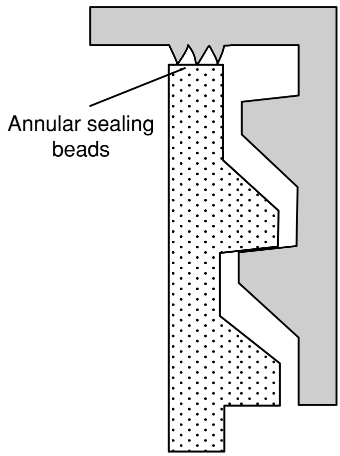


Figure 6.8 Typical 'v-seal' closure.

6.3.2 Liner seals

There are many types of liners (also known as wads) available, and again the choice will need to be carefully made, as this is the essence of the seal. The most common liner materials are those backed with either paperboard, rubber, elastomer or foam polymer (usually polyethylene) faced with a further wide choice of facing materials (Fig. 6.10). Foam polymer liners have largely replaced the older types made from traditional materials such as cork and paperboard, in part due to the wider range of chemical compatibility of modern polymers.

Therefore, the exact conditions of use are important in the choice of liner structure. An expanded foam polyethylene liner in an injection-moulded polyethylene

Figure 6.9 A selection of linerless seal plastic closures. Top left – 38-mm lightweight closure for milk and juice. Top right – 38-mm heavy-duty closure for general use. Bottom – 28-mm closure for general use.

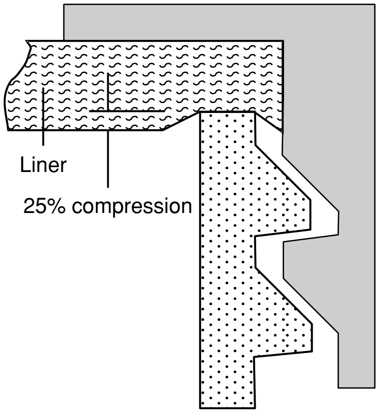


Figure 6.10 Typical liner seal closure.

closure is also considered to be environmentally preferable when fitted to plastic bottles, particularly those also made from polyethylene, as the whole pack can then be recycled without excessive contamination to the recyclate, factors that are of increasing importance in package specification that now has legal compliance responsibilities.

As with linerless closures, good control over application torque is essential to lessen the risk of overriding and damage to the container neck. As a general rule, effective sealing is achieved when the liner is compressed by approximately 25% of its thickness, though this is by no means universal.

Plastic bottles and tubs are ideal for the use of induction and conduction heat-seal liners. The polymers used for manufacturing the container and the seal can be closely matched to give a range of seal characteristics, from truly peelable to totally welded. These methods are considered to offer almost total leakproofness and tamper evidence when properly controlled, hence they are considered high-value products. In their peelable form, they are increasingly used for high-volume food products, where not only can shelf life be extended by excluding oxygen but also customer perception of freshness can be enhanced. Induction heat sealing requires special equipment for generating the heat in the foil element of the liner to weld the polymer element to the neck surface after conventional application of the closure. Where the seal is constructed from polymers that form a welded seal, there may be issues of openability, perhaps linked to contact with hazardous chemicals, such as agricultural pesticides and herbicides. This can be addressed by the closure having a special feature that, when inverted, acts as a cutter to remove the membrane safely. Conduction heat sealing also requires special equipment for pre-welding a foil/polymer laminate disc either hand applied or machine applied, prior to fitting a conventional closure. In the case of small portion-pack tubs, conduction sealing is achieved by welding a wide laminate tape to the rims of a block of filled tubs that are then slit perforated (so that they can be separated by the end user by flexing). Figure 6.11 shows a selection of liner seal closures.

Figure 6.11 A selection of liner seal plastic closures. Top left – Press-on closure with induction heat-seal liner for personal care containers. Top right – 'Squeeze-and-turn' CRC with expanded polyethylene (EPE) liner for hazardous domestic chemicals containers. Bottom left – 'Press-and-turn' CRC with EPE liner. Bottom right – Heavy-duty plain closure with induction heat-seal liner for containers for agrochemicals.

A variation of the liner seal is the ‘O-ring’ washer (Fig. 6.12), notably used for larger plastic bottles and tubs where environment and conditions of use are harsher, requiring higher application torques. The washer can be flat or circular in cross section and is retained between the cap outer wall and an inner skirt, thus preventing displacement at high compression. They can be manufactured from rubbers, elastomers and foam polymers to suit the particular use.

Figure 6.13 shows a typical ‘O-ring’ washer seal closure.

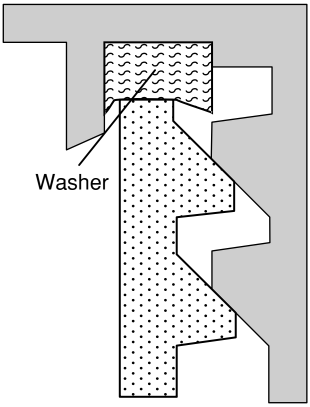


Figure 6.12 Typical washer seal closure.

Figure 6.13 A 59-mm tamper-evident closure with EPE washer seal for industrial and institutional chemical containers.

6.4 Application methods

Screw closures are best applied using equipment that is designed for the particular closure and bottle combination. Adequate care and resources committed to good capping will pay dividends in the form of trouble-free service. In particular, control over tightening is important, particularly for induction heat seal closures, where the tightness will have a direct impact on the effectiveness of the seal. The manufacturers' recommended application torque should be sought and applied in production, whatever the method employed.

It is the screwing action itself that makes capping difficult. Simple hand capping is not recommended due to operator fatigue leading to variable tightness, particularly with tamper-evident or child-resistant types. The use of a handheld torque wrench or other torque-limiting device eliminates this variability, but even this could be considered only for very short runs. Air- or electrically driven handheld screwdriver-type wrenches fitted with a suitable closure chuck provide a low-cost method, but can lead to operator fatigue or even repetitive strain injury in long runs. Careful assessment and limitation of the risks to which operators are exposed is required. Single-head semi-automatic capping machines are more operator-friendly for shorter runs. The filled bottle is placed in a jig under the capping head, which is fitted with a suitable closure chuck into which the closure is push fitted. A safety gate must then be closed to activate the lowering of the rotating head onto the neck of the bottle and apply the screw closure. A torque-limiting device triggers the ascent of the head, and the capped bottle is hand removed. Variations on this theme can give either more or less automation of the process.

Higher speed capping of screw closures is by single- or multiple-head automatic capper, with closures being delivered to the machine by unscrambling gear and feed chute. Chucks are mainly of the sprung-segmented or vacuum type (which grip the closure and apply it to the neck in a 'pick-and-place' unit) reciprocating statically, or in a rotating turret for higher speed; the action and speed of the capper is directly linked to the filling machine. Loading of closures into the capper can be further automated by the use of a hopper feed conveyor.

An alternative and lower capital cost method is the 'spin-on' capper, which uses two contra-rotating rubber wheels between which the bottle, with cap already loosely placed either manually or by pick-and-place device, passes. The high-speed wheels spin the closure down at high speed. Adjustment of application torque is by altering the 'grip' of the wheels and the speed of bottle throughput, though torque consistency is not as good as with the rotating chuck type. It is adequate for most purposes, but close monitoring of wheel adjustment and wear is advisable, and it is not suitable for use where the closure is recessed or obstructed by the bottle handle.

6.5 Push-on closures

Closures that can be applied simply by applying down force are gaining popularity for plastic bottles and tubs, due to the faster filling and capping-line speeds that can be achieved, with less costly equipment. They are also popular for personal care products where they can be moulded in a variety of shapes and colours to match or contrast the container profile, thus presenting a 'one-piece' appearance. There are two main variants: firstly, where an undercut annular bead in the closure pushes over a similar feature on the outside of the neck (Fig. 6.14); secondly, where a finely threaded closure can be pushed onto a similarly threaded neck (Fig. 6.15). The 'bead' type can be engineered either to give a very secure attachment where removal of the whole cap is generally to be discouraged, or (as in the case of a tub) to give an easily removed snap-on tabbed lid. This is becoming very common with the emergence of microwaveable convenience foods such as soups, where the lid has to be removed to allow the end user to peel off the container heat seal, then replaced for microwaving and finally drinking from a pre-formed spout or orifice (see Fig. 6.16). The 'threaded' type gives the end user the facility of a conventional screw closure for re-sealing, and is popular for liquid foods such as fresh milk and juices.

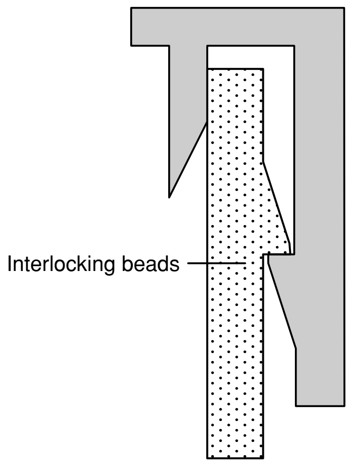


Figure 6.14 Typical press-on closure.

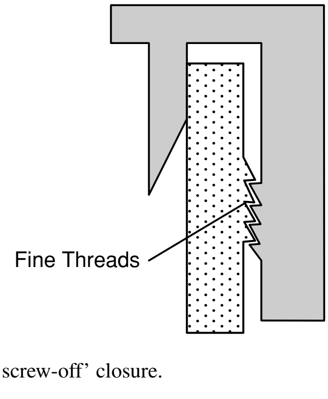


Figure 6.15 Typical 'press-on, screw-off' closure.

Figure 6.16 A press-on polypropylene lid with tamper-evident push-out drinking orifice for microwaveable convenience soup pots.

6.5.1 Sealing media

Most commonly the valve seal and its variants are used, though wads of all types, including induction heat-seals, can be successfully used, as long as the container neck dimensions are closely controlled. With tubs for foods and, paradoxically, some DIY products, conduction heat-seals are also becoming popular.

6.5.2 Methods of application

As the name implies, the closure is simply pushed onto the neck after filling. This can be done by manual pressing or hammering in its crudest form, by semi-automatic or fully automatic presses. Due to the simpler application method, not only does automatic capping require less complex machinery of lower capital cost, but it is also faster, often with lower capping failure rates than screw closures. It can often be done in line; the conveyor taking the containers with closures placed on their necks under a heavy roller or angled top-belt to apply the down force. Attention must be paid, however, to balance between the force required to push the cap 'home' and the top-load resistance of the plastic container. With some ultra-lightweight container types, it may be necessary to incorporate features under the neck into which external supports (for instance guide rails or brackets) can be located whilst the cap is fitted. The temperature of thermoplastic closures at the moment of fitting will also have an effect on the ease of application, and control of storage temperature is recommended. 'Press-on, screw-off' closures require a tab moulded on their outside rim to orientate them through an automatic unscrambler and feed chute, so that the closure is in the correct position of tension in relation to the sealing surface.

6.6 Flip top and sports closures

In order to permit quick access to the container, flip top closures have become popular particularly for personal care products, and also generally for situations where either one-handed operation or sifting and controlled measure dispensing is desirable. They can be either screw types or push-on types, but commonly have an integrally moulded hinged sealing 'lid', machine closed after moulding to permit conventional capping, that seals onto the cap itself by friction fit (Fig. 6.17). The lid is opened either by flicking up a thumb tab, which activates an over-centre hinge device to flip up the lid, or by squeezing the cap sides with the same effect. The former opening method is typically seen in branded cleaning fluid, dish-wash detergent containers and squeezable sauces. The latter is more usually applied to personal care products such as shampoos and gels, incorporating one-way valves for inverted use, such as shower-gel packs where the lid can be left open. Hybrids of the two are increasingly being used to dispense sauces, to which they help maintain

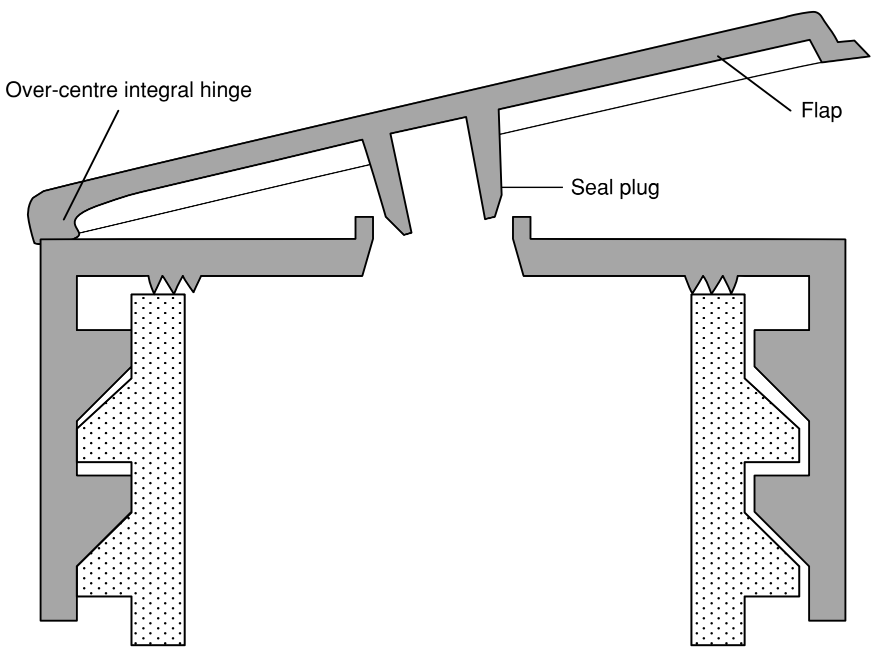


Figure 6.17 Typical flip-top closure.

cleanliness after dispensing and provide the facility for inverted storage. Variants include directional nozzles for liquids such as toilet cleaners that can be raised from a ‘closed’ position flush with the top of the closure, and for sifting or controlled measure pouring of powders and granules such as salt or cleaning products. In the latter case the lid may have a single ‘flap’ that lifts to reveal either multiple holes for sifting or a larger opening for pouring or shaking. Some may have two diametrically opposite hinged ‘flaps’ offering both options.

The use of sports closures has grown dramatically with the burgeoning ready-to-drink ‘health’ beverage as well as children’s convenience beverage markets. They are typically three-piece assemblies comprising a traditional polypropylene linerless screw cap with capture ring tamper-evident device, a polypropylene pull-up drinking nozzle with integral seal and a protective overcap usually moulded in a clear, rigid polymer such as polystyrene, which will also have a ‘break-free’ tamper-evident feature. Assembly is done by post-moulding automation. Close dimensional control during moulding is essential to prevent either assembly problems or subsequent leakage and openability problems. Figure 6.18 shows a selection of flip top and sports closures.

Figure 6.18 A selection of flip-top, directional nozzle and sports closures. Clockwise from top right: 28-mm tall closure with directional nozzle for household cream cleaner bottles; 28-mm closure with directional nozzle for household hygiene chemicals bottle; Sports closure with pull-up nozzle and tamper-evident overcap intact. Sports closure with pull-up nozzle shown with tamper-evident overcap raised. 30-mm closure with flip-top and induction heat-seal liner for squeezable sauce bottles; Press-on closure with flip-top for personal care products.

6.6.1 Methods of application

Flip top and sports closures can normally be applied by the methods previously described for screw and push-on type closures.

6.7 Tamper-evident devices

Virtually all of the closure types described herein can be manufactured to incorporate tamper-evident devices, though this is more difficult with thermosetting materials that will require separate components. Thermoplastic polymers such as HDPE and PP can have tamper-evident features integrally moulded. The main types for screw closures are those incorporating a band around the bottom of the closure, attached either by small ‘bridges’ or by a thin membrane through which the hot polymer flows during injection to fill the band. The band can either carry pawls that engage on ratchets around the base of the container neck (Fig. 6.19), or carry an annular bead that is forced over a similar feature on the container (Fig. 6.20). With either type, the bridges or membrane breaks when the end user either unscrews the closure or grips a tab and tears off the band (known as tear band), which can either be retained on the neck (or, in the case of tear band, on the closure by a strong link) or be freely removable. The former is preferable in situations where the band could cause problems if it fell off while the container was tipped for pouring, such as when dispensing motor oil or filling a drinks reservoir with concentrate. The latter is ideal where absolute evidence of tampering or pilfering is required, as it is visually obvious that the pack has been opened. For tubs and pails, recent developments include the break-tab type, which releases tension in the band thereby allowing the lid to be easily lifted off.

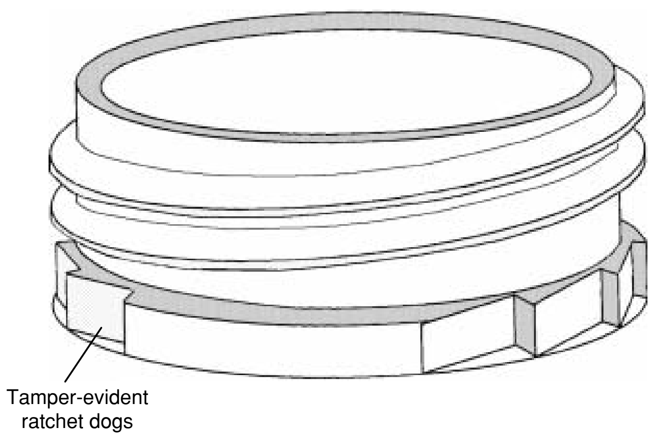


Figure 6.19 Typical ratchet-type tamper-evident feature.

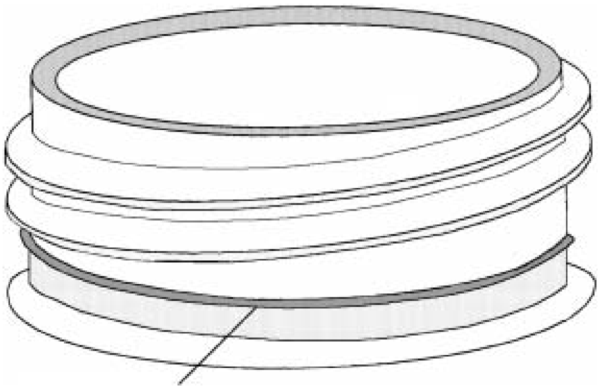


Figure 6.20 Typical capture bead type tamper-evident neck.

Application of tamper-evident closures requires a little more care, due to the possibility of breaking the band on application, and the speed of rotation or down force needs careful control. Addressing this problem by increasing the bridge strength brings with it the potential for (justifiable) consumer complaints of poor openability – an ever more important topic for the packaging industry, with a population where the elderly represent an increasing percentage. A development involving the moulding of the bridge as a membrane, followed by the cutting of annular slots into it as a post-moulding operation, has successfully addressed this issue. In general, design of the bridges or membrane and dimensional control in manufacture of both closure and container neck are critical to the performance of the device. Figure 6.21 shows a selection of tamper-evident closures.

6.8 Child-resistant closures

The two main types of child-resistant closures (CRCs) are those either requiring down force to engage ratchets or requiring the closure sides to be squeezed to disengage pawls whilst unscrewing the closure. The former is usually more expensive, being a two-part device requiring assembly, but has advantages in that as no special features are needed for the container neck. The latter needs to have a generous double wall with a consequently smaller neck aperture for a given outside diameter, and also requires the neck to have moulded engagement dogs (Fig. 6.22). The need for these to be robust to avoid puncturing can compromise lightweighting. Figure 6.23 shows a selection of child-resistant closures.

Figure 6.21 A selection of tamper-evident plastic closures. Clockwise from top right: Large closure with ‘break-free’ pawl-type tamper ring, shown after removal; Small closure with post-moulding blade-cut ‘break-free’ captive-type tamper ring, shown partially removed; Lightweight closure with ‘pull-tab’ pawl-type tamper ring, shown partially removed; Large closure with ‘pull-tab’ pawl-type tamper ring, shown partially removed.

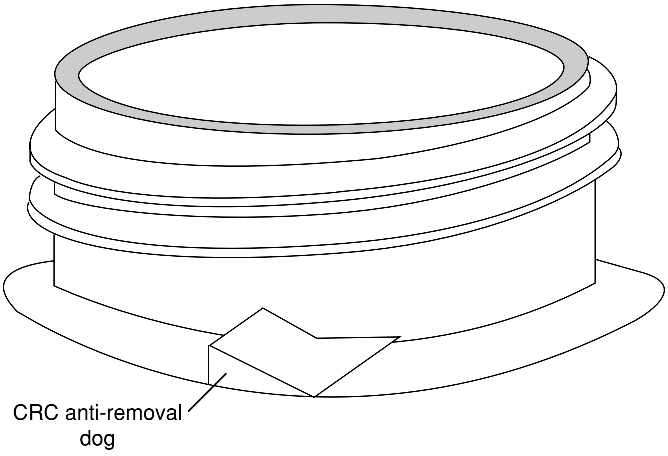


Figure 6.22 Typical ‘squeeze-and-turn’ CRC neck.

Figure 6.23 A selection of child-resistant plastic closures. Clockwise from top right: 'Push-and-turn' type two-piece CRC – top view; 'Push and turn' type two-piece CRC – internal view; 'Squeeze-and-turn' type two-piece CRC – top view; 'Squeeze-and-turn' type one-piece CRC – top view; 'Squeeze-and-turn' type one-piece CRC – internal view.

6.8.1 Methods of sealing

Sealing methods are the same as for conventional closures, but these can also influence the effectiveness of child resistance, and close dimensional control of the container neck height is essential to ensure that the device meets its legal performance requirements.

6.8.2 Methods of application

The methods used are also the same as for conventional closures; however, application of CRCs can be difficult due to their inherent need to prevent easy opening by children. Deliberately, very little grip is provided on the outside of the closures, and this can mean difficulty with all means of capping. For press-and-turn types, the best designs of chuck are those with knurled jaws that close completely around the circumference to give a firm grip whilst applying. For squeeze and turn, care is needed to ensure freedom for the outer wall to deflect over the container neck dogs during application. This must also be done at speeds that prevent shock damage to both components.

6.9 Roll-on pilfer-proof closures

These are typically used for airline in-flight alcoholic drinks that are packed in plastic containers to take advantage of their lighter weight, and yet need to retain a ‘traditional’ closure system. The principal requirement is that the neck should be robust and with a strong thread profile to facilitate forming of the metal closure thread during roll on. The methods of sealing are identical to those used for glass bottles, though the instability of the small, light containers usually requires stabilising features on feed conveyors during filling and capping.

6.10 Spray pumps

There has been a massive increase in the uses for spray pumps in recent years, due to the convenience of having the chemical agent at its optimum effectiveness for the job. Plastic bottles are eminently suited for this purpose in a wide range of markets, notably for personal care and automotive, home and institutional cleaning applications. Spray pumps can be fitted with either screw closures or ‘press-on, screw-off’ closures. The former will usually have an ‘anti-back-off’ feature in the bottle neck that significantly increases the security of the closure during the last turn of the thread. This addresses early end-user complaints that accidental rotation of the spray head led to leakage from the neck/closure interface. Early types that prevented the end user from removing the pump after fitting, by engaging closure locking pawls with neck ratchets, have largely been replaced by removable versions due to environmental concerns over the recyclability of the multi-material pump in kerbside and ‘bring’ collection schemes, where removal of the pump not only allows the bottle to be recovered, but also promotes reuse by refilling. Figure 6.24 shows a typical spray pump fitted to an HDPE flask.

6.10.1 Methods of sealing

Foam polymer washer or linerless valve seals are usually employed due to the limited space in the closure, which has to carry the liquid delivery tube through its centre. ‘Press-on, screw-off’ types demand that the bottle neck dimensions be closely controlled to ensure ease of fitting, security and leakproofness.

6.10.2 Methods of application

High-volume production where a simple screw closure is fitted usually requires a sophisticated machine that is bespoke to the pump/bottle combination, the main difficulty being the need to maintain the pump in the correct orientation whilst its closure element is screwed home, using the ‘spin-on’ method of screwing on the closure as described earlier. ‘Press-on, screw-off’ types have the advantage that

Figure 6.24 A typical trigger-spray pump fitted to an HDPE flask for general household, garden, automotive or veterinary products.

simply pressing it onto the neck can fit the pump – the two-part construction of the closure element permitting the outer to be unscrewed, leaving the inner locked onto the neck. The high capital cost of unscrambling the pumps by machine means that a large measure of hand insertion and/or feeding of the pump is prevalent. As mentioned in Section 6.5, the bottle top-load resistance is critical, and material distribution control measures are strongly advised.

6.11 Dispensing pumps

These are prevalent among smaller and larger packs, both bottles and tubs, across a wide range of markets from personal care to industrial chemicals, where either controlled dosing of liquids, creams or pastes or accurate delivery from a larger to a smaller vessel is desirable. The bottle/closure interfaces are the same as those detailed for spray pumps above, as are sealing and application methods, and the requirements that apply to plastic containers. The nozzle component has usually to be unscrewed from the pump body before use, preventing accidental transit spillage. Pumps are sometimes supplied as a separate component to be fitted by the end user,

Figure 6.25 A typical pump dispenser for skin care and soap products. Note threaded nozzle neck for transit closing.

especially with large containers for use in industrial applications. In these cases the pump closure will be a near exact copy of the transit closure fitted to the container. Figure 6.25 shows a typical dispensing pump closure for hand-wash soap.

6.12 Secondary seals

The use of secondary seals with modern closure systems on plastic bottles and tubs is largely unnecessary, though some products traditionally still use them, notably some DIY chemicals. They take the form of a plug or shive that is a push fit into the bore of the plastic container, where it seals in much the same way as the valve of a linerless closure. The plug is removed either by having a pull tag integrally moulded, or by the use of a tool such as a screwdriver being driven through for prising out the seal. Though a dispensing aid rather than a secondary seal, plugs incorporating a jet nozzle for products, such as toilet disinfectants can also be supplied pre-fitted into a screw closure, often child resistant, which when removed reveals the nozzle.

6.13 Conclusion

It can be deduced from this chapter that achieving a good seal to plastic bottles and tubs is not that simple, nor is it for any container type or construction. History records countless examples of poor closure of containers causing terrible financial loss in shipment, sometimes with associated disastrous damage to ships, aircraft and loss of life. In most of these cases the root cause was human error, either in the choice or application of the closure. In the modern world however, we have the advantages of both centuries of experience and a wondrous selection of polymers from which to manufacture containers and closures; nevertheless, the incidences of leakage from even the most heavily designed and developed plastic packages is still exercising the loss-adjuster's pen as we speak! Yet, all of this misery could be avoided by following a few simple rules.

- Select components materials carefully, taking into account the life cycle of the package, from manufacture right through to final disposal. Conduct a documented life cycle analysis, and consider techniques such as FMEA, which often reveal potential problems early on so that preventive measures can be applied. Do not rely on manufacturers' technical information alone to prove suitability – their advice though useful will apply to 'best practice' handling and use of their products, which exists only in a perfect world seldom experienced! Plastic materials may be seen as 'wonder' materials that are totally inert and dynamically strong. This is not always the case. In particular, chemical compatibility and durability trials conducted either by yourself or by a trustworthy independent laboratory can pay dividends. This is especially true where extremes of climate are encountered in the life cycle. Most plastic are softened by heat and embrittled by cold. Add contact with certain chemicals together with a bit of 'rough and tumble' and the results can be catastrophic!
- Ensure that you have a comprehensive, agreed specification for all components and that suppliers have adequate systems in place that will ensure you receive consistent product quality. Engender supplier partnerships by informing them of your use of their products and the critical parameters you need. These may not be the same as those they have chosen for general market use, which can be a nasty shock when you make your first complaint due to failure in service.
- Conduct pilot trials prior to full implementation, using the life cycle analysis to verify the prevalent conditions of use at all stages. This means a sizeable sample such as a vehicle load, rather than a few 'quick and dirty' tests done in the staff toilets. Take account of any inherent variability in the components and the conditions of use to ensure that 'worst case' scenarios are evaluated. If finances are available, employ the services of an independent laboratory that is an expert in this field. Money spent at this stage pays handsomely in the avoidance of costly recalls and claims and consequent loss of prestige.

The allocation of adequate financial resources at the front-end project stage is not optional; it is essential – however tight the budget!

- Constantly review and update the documentation, particularly the product specifications and life cycle analysis or FMEA. Things change! Experience shows that the majority of unforeseen problems happen when changes, sometimes quite subtle, occur. As with suppliers, encourage partnership with all agencies in the product's life cycle, and make it a condition that all changes in practice are discussed, evaluated and agreed to, prior to implementation, especially where the changes are being made as cost-reduction measures. All this effort would not be wasted. It can form a protocol that can be incorporated into SOPs for future product development projects.
- Provided these precautions are taken, the likelihood of successful application and use of closures for plastic bottles and tubs will be greater.

7 Push-on closures

Nigel Theobald

7.1 Introduction

Most of the packaging containers outlined in previous chapters are able to use push-on or snap-on closures. The function of such closures is principally to give a secure closing of the container, either as a primary closure or as a secondary closure, thereby keeping the contents 'fresh'. As with all closures, the effect of closure and the resultant seal relies heavily on the compatibility of the two surfaces to be closed: the surfaces must 'mate' with each other in order to produce an effective seal. All the surfaces also need to be clean because any contamination would result in a poor seal. Indeed, poor seals are often found to be the result of dirty sealing surfaces. Even the smallest contamination can give rise to a seal that will either admit moisture or allow the product to seep out.

Push-on or snap-on closures can be manufactured using many different materials and can be fashioned in such a way as to be capable of being either pried off or snapped off. The main difference between push-on and snap-on closures are the methods employed to provide a secure closing to the container. With push-on closures, the closure generally fits within the confines of the container and therefore the mating surfaces must be a good fit to achieve a good seal. With snap-on closures, the closure usually fits over the container and thus the closure must have a degree of flexibility to be able to 'snap' over the rim of the container.

Some closures are of a compound type, where the action may be push on and twist off. A good example of this type of closure is used in the instant coffee market, where the closure is designed to push on, but it is screwed off when the consumer is using the product. In this instance, the primary closure (for hermetic sealing) is usually a diaphragm sealed to the container as this type of closure does not produce a sufficiently good seal for the long shelf life products.

Particular differentiations can be made between push-on and snap-on closures, and these differences are discussed in more detail in the following sections.

7.1.1 Push-on closures

These are closures that can be applied to the container in such a way that the closure forms a seal between the product and the surrounding atmosphere. The action of closing the container does not normally require any turning force or any adhesive force to retain the closure – indeed, the main action is for the closure to be pushed into the opening at the top of the container. In the latter case, the closure and the container are usually made of similar materials – for example, a metal can with a metal lid or a plastic can with a plastic lid. There are some instances where the push-on closure may benefit from a turning force to secure the closure into position. There is, in fact, no clear distinction between push-on closures and some of the twist-on varieties. In this chapter we will discuss some twist-on closures that are similar to the standard push-on variant.

7.1.2 Snap-on closures

A snap-on closure that is applied to the container utilises a physical deformation of the closure past a lip on the container to hold the closure in place once applied. Thus, snap-on closures may be considered to be a sub-category of push-on closures, but the appellation enables a slightly more precise indication of the closure function. Most snap-on closures are manufactured from one of the plastic materials, where the ability to 'stretch and relax' is exploited in order for the closure to snap over the retaining rim of the closure. However, there are examples of snap-on closures using tinplate. This is seen in some shoe polish tins, where the tin and the lid are slightly different in shape (slightly ovoid) and the exploitation of the ability of the tinplate to flex is used for creating a good seal.

7.2 Closure function

Although the primary function of many closures is to seal the container throughout its shelf life, this is not always the function of the push-on closure. Many applications for push-on closures are as a secondary sealing function, either once the primary seal has been breached or, for example, to hold leaflets between the primary and push-on closures. There are cases where the push-on closure is used for the primary seal and no other seal is used. An example of this is with shoe polish, where the metal lid of the container is squeezed at the side to remove it from the container and then replaced with a snap-on action. However, the total hermetic seal of the container is not necessarily needed for the closure to perform satisfactorily; a partial hermetic seal may well be acceptable as any change in weather conditions may not have a detrimental effect on the product over the projected shelf life of the product. Thus, the product itself may be sufficiently stable so that it does not require a total hermetic seal. The majority of products, however, do require a good seal between the container and the closure to keep the product in a 'factory fresh' condition up until the initial opening of the container.

7.3 Metal closures

Metal push-on closures are mainly of three distinct types: (i) push-on, pry-off closures used for cans (paint cans and food cans for example) (ii) 'crown cork' crimped-on and prise-off closures used in the packaging of beer and carbonated drinks and

(iii) push-on, pull-off closures used for the smaller cans of paste-type products such as shoe polishes.

7.3.1 Push-on, pry-off closures

The function of this type of closure relies on a friction fit between the container and the closure. It is essential that the container and closure tolerances are kept to very tight limits and that the angles or slopes at the fit surfaces are accurately calculated (see Fig. 7.1).

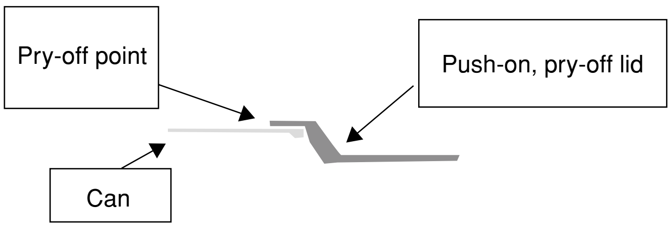


Figure 7.1 Schematic of push-on, pry-off lid.

The lid is pushed onto the container and the slope on the lid engages with the orifice of the container so that a tight fit is obtained. When the container is required to be opened, a tool (such as a screw driver) is inserted into the gap between the container and the lid (the pry-off point is indicated in Fig. 7.1) and the lid is levered off, thus removing the lid from the container. The lid can usually be levered off from anywhere around the perimeter of the container/lid interface. However, in some containers, there is an area on the closure where the rim is slightly relieved. This allows easier access for a tool to be used to pry off the closure and to access the interface between the closure and the container. The taper on the container and the closure are used to create a good seal and allow for any minor distortions of the system in use. Thus, if the container aperture increases in size (mainly due to the 'set' of the container material over time) then the closure can still accommodate the size change by sitting down on the taper of the closure. It is normal with this type of closure for the closure and the container to be manufactured from the same material. Usually the metal used is tin-coated steel (tinplate) as the forces required to give a good seal are fairly high and both the container and the closure must be capable of withstanding the high pressures generated (Fig. 7.2).

This type of container closure is highly efficient; however, it is liable to damage that will cause the seal to become inefficient. Such damage may come from a distortion of the container (through dropping or physical mishandling), contamination of the seal area (with product or dirt, for example) or by distortion of the lid (through constant removal or buckling). It is difficult to correct the damage here and it may also affect seal efficiency.

Figure 7.2 Lever lid container.

7.3.2 Crown cork closures

This type of closure is usually applied to glass containers and is mainly used for effervescent products, such as beer and soft drinks. However, it may also be applied to plastic containers, provided that the body of the container is sufficiently robust to withstand the pressure required to apply the closure in the initial application. Crown cork closures are predominantly used for single-application use products, because once removed the closure is normally distorted and becomes ineffective for re-closure (Figs 7.3 and 7.4).

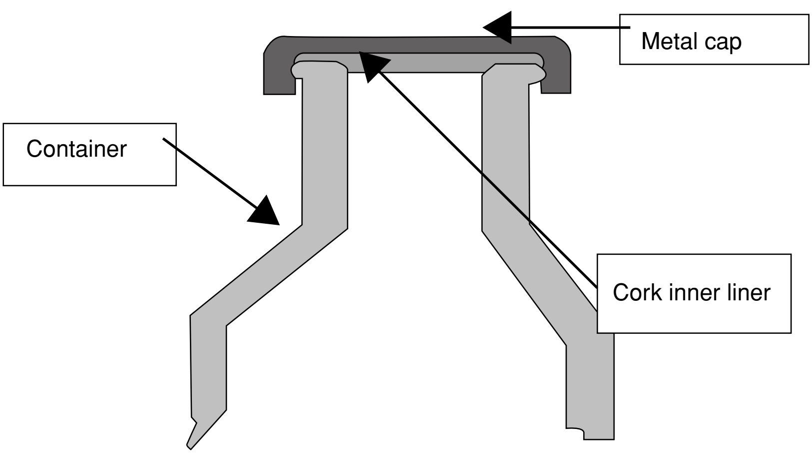


Figure 7.3 Schematic of crown cork closure.

Figure 7.4 Crown cork on a glass bottle.

With this type of closure, the metal (usually tinplate) outer shell of the closure has a ribbed side wall that is formed by the crimping tool on application. This allows the closure to be held firmly onto the container by being crimped under the retaining ring on the container. Inside the closure is inserted a ring of cork (hence the name *crown cork*) that will act as the sealing membrane to the container. When the closure is applied, the capping machine exerts a downward pressure sufficient to compress the cork layer and at the same time it squeezes at the base of the closure to seal around the lip of the container, thus preventing the closure from coming adrift. In order to remove the closure, a tool (bottle opener) should be inserted under the lip – between the bottle and the closure – and the upward pressure distorts the closure over the rim on the bottle, thereby releasing the closure from the bottle. Typically, crown cork closures that have been removed are so bent that they cannot be reused.

Crown cork closures are excellent for containers that hold a product that exerts pressure on the closure/container interface, such as beer or carbonated soft drinks. This is attributable to the two sealing and containment actions that take place during the sealing of the closure to the container. The first of these actions is the compression of the seal of cork, and the second is the clamping of the metal outer case of the closure under the rim of the container. Cork is an excellent sealing membrane, because it has the ability to seal over an irregular surface and, when wetted, it has a tendency to swell, thus forming a better seal. However, if the closure is sealed when wet, and then allowed to dry out, the cork liner will shrink and, if the capping pressure is low, may result a seal failure. Crown cork closures have an excellent record of success and reliability.

A slightly different version of this type of seal uses a flowed-in liner rather than the cork insert (see Fig. 7.5).

Figure 7.5 Flowed-in liner in place of the crown cork.

The liner is a ring of a soft plastic material around the inner circumference of the cap. With this type of closure it is also possible to add a screw thread to the container (Fig. 7.6), and thus result a reseal of the container. Here the plastic material extends down the side of the inner surface of the closure and forms the thread profile when the closure is applied to the container. With this variation, the end of the closure does not seal around a retaining ring in the container (as with the original crown cork closures), but relies for the retaining action on the configuration of the threads on the container. If the retaining ring used in the original version was evident then this would negate the possibility for this type of closure to be resealed. Again, here as with the original crown cork closure, usually the closure is of tinplate and the container is glass. The main reasoning here is that the containers are again generally used for effervescent liquid products and the high internal pressures generated require the strengths of these materials.

7.3.3 Push-on, pull-off closures

There are two main variants in this type of closure: (i) where the container has a lip over which the closure fits, thus relying on the friction between the container and the closure to maintain the seal and (ii) where the container is a fixed shape (usually circular) and the closure has a slight distortion. In the latter, the application of pressure will allow the closure to be released from the container.

In this instance (see Fig. 7.7), it can be seen that, when the closure is applied, it must be capable of being deformed over the locating ring around the container. This is achieved by allowing the closure to be sufficiently flexible to distort when the closure pressure is applied. The temporary distortion is seen as a slight inward

Figure 7.6 Bottle thread for reseal.

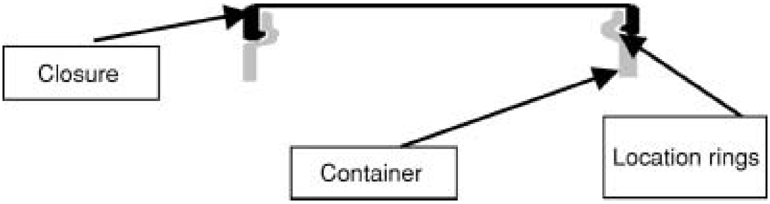


Figure 7.7 Schematic of push-on, pull-off closure.

bowing of the centre portion of the closure as the closure is pushed on. This distortion is corrected by the flexibility of the closure material, once the closure and container locating rings have passed each other, then the closure is held fast. To allow for low release pressures, the locating rings have a rounded profile that allows the closure to be removed with an equal pressure to that of the closing.

A variation of this closure is seen where the closure can be pushed on, but a squeeze action is required to remove it (Fig. 7.8). In this variant, the locating ring on the closure is interrupted (at the point where the squeeze action is required), making it easier to distort the closure and remove it from the container. It is essential in this

Figure 7.8 Push-on, squeeze-off cap.

closure system to mark on the closure exactly where the locating ring interruption is – because, without this, squeezing on any other point of the closure will not release it from the container.

In Fig. 7.8, it can be seen that the squeeze point is indicated by the semicircle of lettering at the lower left-hand quadrant (the wording says 'press to open'). By pressing at that point, the lid is distorted and the metal of the lid flexes to allow the rim on the lid to be pushed over the rim on the container and the container to be opened. Figure 7.9 shows the detail of the rim on the lid with the interrupted ring showing at the top of the picture.

Figure 7.9 Push-on, squeeze-off lid.

A variant of the push-on, pull-off metal closure is used for products, such as jams and preserves, where a vacuum seal is made to help retain the closure onto the container.

With this type of closure, there is a slight thinning of the metal of the closure in the centre section, with the latter also raised to form a dimple (see Fig. 7.10). The closure is secured to the container, either by a continuous thread profile on the container, or by an interrupted thread. With the continuous thread, the closure can only be positioned by a screw action when it is placed on the container. However, if an interrupted thread is used, then the closure can be pushed onto the container when assembled and screwed off. The action of the closure in both cases is identical.

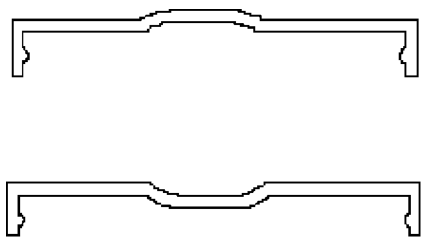


Figure 7.10 Schematic of vacuum cap.

With the dimple in the normal manufactured position (dimple up), the closure is assembled onto the filled container. The filled container is usually filled with hot product, because the action of cooling (once the container is sealed) creates a vacuum in the headspace between the product's upper surface and the lower surface of the closure. Once the closure is in position, the vacuum created pulls the metal of the dimple area down and forms a concave area in the closure surface. Releasing the closure releases the vacuum in the container headspace and the dimple clicks back into its manufactured state; the characteristic 'click' can be heard when the vacuum is released.

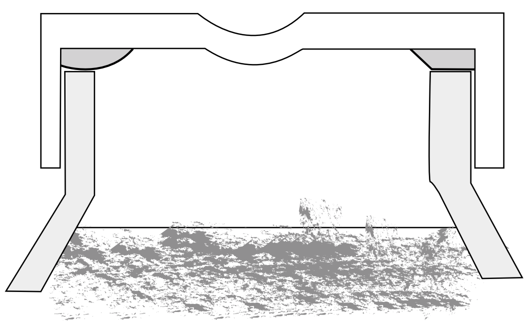


Figure 7.11 Schematic of filled container with vacuum cap.

Figure 7.11 shows the effect of the cap (dimple down) in place with a vacuum created in the headspace by the cooling product. Once this vacuum is achieved, the closure is forced harder onto the container and creates a more effective seal, which is hard to break. The flowed-in liner compound, around the sealing area, increases the seal efficiency, especially where there are small defects in the perfect flatness of the seal areas on the container and the closure. The moulding process is liable to give a small witness line in the seal area where the two halves of the moulding tool meet, especially with glass containers, and also with some plastic containers. This is usually referred to as ‘line over finish’. When the closure is either unscrewed or prised off, the vacuum is released in the headspace, and the dimple snaps from the concave to the original convex position. The closure can then be easily released. This is illustrated in Fig. 7.12.

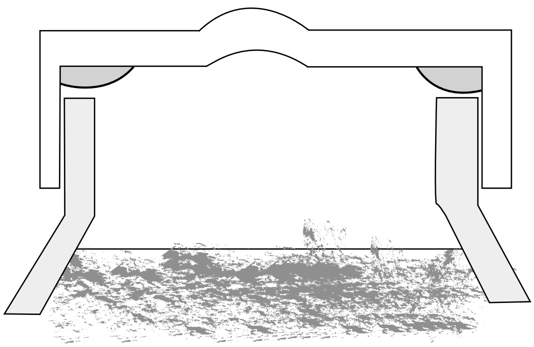


Figure 7.12 Schematic of partially opened container with vacuum cap.

This type of closure has several inbuilt features that make it desirable for many applications where some degree of confidence in the package security is required: the sound of the ‘snap’ while releasing the closure gives the consumer some confidence that the product is in ‘factory fresh’ condition. In addition, this snap has a degree of ‘tamper evident’ assurance for the consumer, because once the container/closure seal is broken, the closure will not deform (to give the snap sound) without being able to reapply a vacuum in the headspace.

It should be remembered, however, that a determined pilferer will be able to replace the cap in such a way that the central button is in the concave position, and will snap-on opening even after they have pilfered with the product. There is no such thing as a pilfer-proof pack. This will be stressed in other chapters of this book and I make no apologies for adding it here.

7.4 Plastic closures

Most of the types of plastics can be used for push-on closures, with the main criteria being the container type and the degree of protection required for the product. By far the most common is *low-density polyethylene* (LDPE). This is mainly because of the ability of LDPE to flex over a retaining feature on the container and flex back to its original shape after being deflected. The most common example of this type of closure is the push-on lid, which is used for sealing the container either as a primary seal, or as a secondary seal for re-closing after the initial seal has been broken. Plastic closures can have applications where, as shown in the previous section on metal closures, the closure and container are made from similar materials. Thus, a plastic lever lid is possible, and frequently used, where the container is also of a plastic material. Plastic paint cans are replacing metal cans as the advantages of the plastic container outperform the metal equivalent. Plastic cans for paint, for example, show superior damage resistance and also superior product protection while in use.

Figure 7.13 Container with over-cap, diaphragm seal and spoon in place.

The examples illustrated in Figs 7.13 and 7.14 show a hinged lid with a space underneath for a spoon prior to the diaphragm seal. As can be seen the diaphragm seal is also used to give an indication of tamper evidence. The lid, however, gives sufficient sealing properties for the product during its 'in use' life. The true seal is given by the diaphragm for its 'shelf life'.

There are many examples of these types of closures – from secondary seals on metal cans to cover caps on aerosols. It should be remembered that in the injection moulding process the elements that affect the final size of the component are not simply related to the size of the cavity in the mould tool; moulding temperature, injection time, injection dwell time, cooling time and mould temperature all play a part in achieving the required size for the moulding. In addition, the material grade and the colour match may also have an effect on the finished dimensions of the moulding.

Figure 7.14 Container with over-cap and diaphragm seal broken.

7.4.1 Snap-on closures

Snap-on closures are popular for the application of over-caps and as covers for items such as food containers and aerosol cans. Many of the over-caps rely on their ability to deform over a locating ring on the container and lock under it, without any destruction of either the closure or the container. Where any excessive force is required to locate the over-cap, the closure may become damaged over time. It will also be found that the consumer cannot re-site the over-cap correctly during use, thus negating the effectiveness of the closure system.

In Fig. 7.15, the locating ring on the closure snaps over the locating ring of the container when downward force is exerted on the closure. The closure must have sufficient elasticity to deform over the container locating ring without splitting. Furthermore, it is essential that the container has sufficient stiffness so that it does not deform when pressure is applied to the closure.

Most of these types of closures are injection moulded, so that the correct fit can be obtained between the closure and container without any undue retained stress in the closure after the lock rings are engaged. If the tolerance between the closure and the container is such that the closure is under excessive pressure after closing, then there is a high probability of the closure ‘cracking’ under the stress.

The stresses on the closed package from the container to the closure are shown in Fig. 7.16. The initial stress is for the locating ring of the closure to be forced outwards; this creates additional forces on the closure where the sidewall meets the top face, resulting in the pivoting action at the junction of the sidewall and the top face. Thus, the sidewall is forced outwards and upwards, with the top face being pushed downwards into a concave ‘dishing’ of the top. These pressures result in

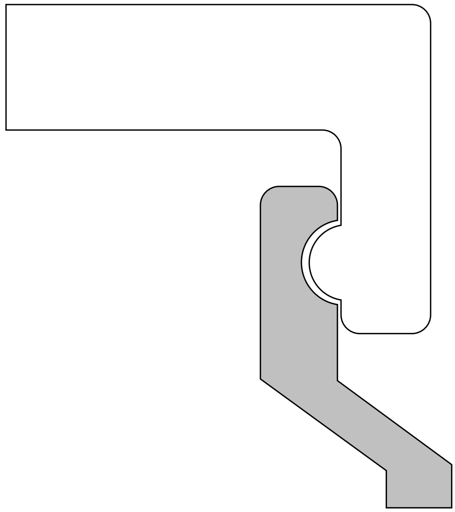


Figure 7.15 Schematic of typical snap-on plastic cap.

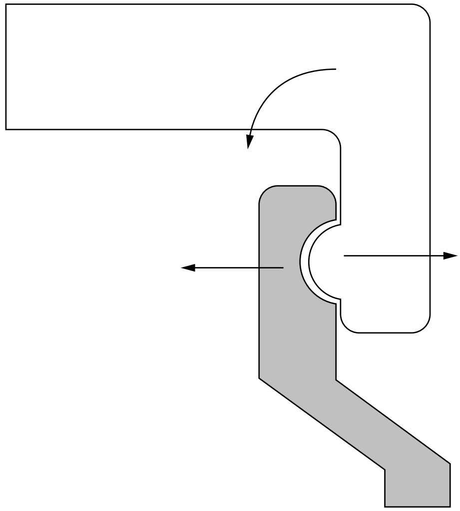


Figure 7.16 Stress forces in closed package.

the closure becoming insecure and liable to be dislodged with any external forces applied to it by way of a physical knock. There are also stresses built up within the plastic materials, which could lead to cracking of the closure itself.

All plastic moulded materials contain internal stresses that are 'frozen in' during the moulding or forming processes. Injection-moulded caps are no exception, and any external stress on the moulding will tend to add to the moulded-in stresses to assist with closure failure. Good, tight tolerances are required if the closure is to achieve its function satisfactorily. Too loose, and the closure seal will not be effective; whereas, too tight, and the stress forces will aid accidental removal or cracking of the closure Fig. 7.17 shows some typical uses for snap on caps.

Figure 7.17 Typical application of an over-cap on aerosols.

7.4.2 Hinge lid closures

This type of closure is again usually injection moulded; it is a single moulding with the lid and retaining ring being held together with a hinge (Fig. 7.18). The usual material is polypropylene (PP), because this material possesses the requirements necessary for a strong flexible hinge that will not break under repeated action. The closure is moulded with the lid portion and the retaining ring in the open position, thus allowing for a one-piece moulding. The hinge is moulded between the cap and

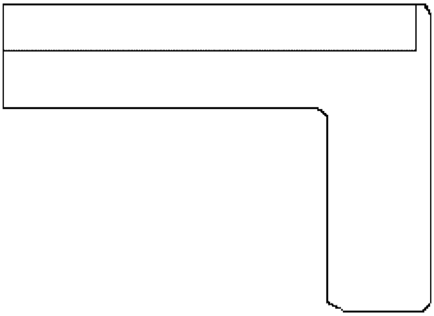


Figure 7.18 Schematic of hinge lid closure (side view).

the retaining ring, which is the only point where the two parts join. Figure 7.19 shows a plan view of the moulding and the reduced thickness at the hinge area on the right-hand side. The lid has been omitted to aid clarity.

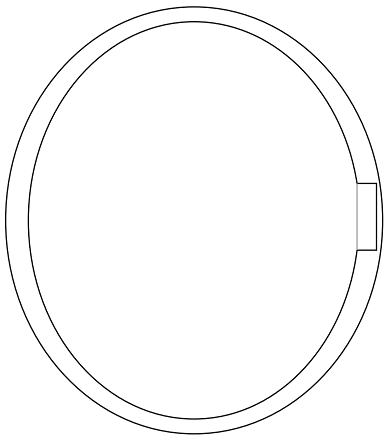


Figure 7.19 Schematic of hinge lid closure (plan view).

Although the hinge area is reduced, it is essential that the locking ring (on the retaining ring) is not interrupted, as this will compromise the security of the closure on the container. The locking function of this type of closure is the same as for the snap-on cap in Fig. 7.15, both for the lid-to-closure seal and the closure-to-container seal. More care must be exercised in this type of closure when moulding, because there are more sealing surfaces to be considered, namely, the sealing of the locking ring to the container and the sealing of the hinge lid to the locking ring. Figure 7.20 shows a typical view of the hinge area.

It can be seen from Fig. 7.21 that the cap is retained in the open position by the inclusion of a projection in the moulding at the rear end of the internal face, which is a friction fit to the container when open, but rests inside the container in the closed position.

7.4.3 Push-on, twist-off closures

This type of closure is now common for many products, such as instant coffee, where the closure is pushed onto the container and engages in the thread of the container, thus securing it to the container. The act of removal is by rotating the closure in an unscrewing action. The locating profiles of both the closure and the container are in the form of an interrupted thread. This allows the closure to be easily pushed onto the container and for the closure to be removed by a short twist (about a quarter turn). The thread profiles are an important factor here, and have been developed by the container and closure manufacturers in concert, so that the desired effect is consistent

Figure 7.20 Typical snap-on hinge lid closure and container.

Figure 7.21 Hinge lid closure in open position.

with consumers' expectations. It is emphasised here that both the container and the closure manufacturers must cooperate with each other to achieve the desired results. Moreover, separate technologies of the container manufacturer and those of the closure manufacturer alongside each other with their relevant manufacturing tolerance limits need to be addressed to achieve a secure seal. For example, the achievable tolerances in glass moulding and injection moulding in plastics do vary, and so the seal efficiency, both before first use and during subsequent opening and storage, needs to be addressed. It cannot be assumed that a closure that has been manufactured for a glass container will be acceptable for a plastic container without some modification (Fig. 7.22).

Figure 7.22 Push-on, twist-off seal.

It can be seen in Fig. 7.23 that the thread is not continuous but is in four segments, making it possible for the container to be opened with just a quarter turn of the closure. Many of the containers used with this type of closure are designed to be non-cylindrical. This allows the user to be able to line up the closure and the container, snap on the closure, and thus to ensure that the closure is in the closed position. Many of the closure systems of this type use a diaphragm seal, as the primary seal the application of the closure is not considered to be sufficiently moisture-proof to give the desired shelf life for the product.

The addition of a wad within the closure is sometimes used to aid the closure seal after the initial opening. The wad will be made from a material that will deform when the closure is pushed into place. This is evident when the closure is removed as the deformation can be seen in the closure liner. The wad must also be sufficiently

Figure 7.23 Thread detail of push–on, twist-off closure.

robust to allow for recovery during the repeated closing and opening actions of the container and closure in use. This recovery action is rarely the full recovery to the original size and shape of the liner and some deformation is always seen. Lack of evidence of the deformation is usually an indication that the seal was not effective.

7.5 Closures for tubs

Most of the closures used for tubs are push-on closures, and these are usually either vacuum formed or injection moulded and made of plastic materials. Vacuum forming is the cheaper option, but the tolerances within the construction are of a wider nature than the injection-moulded variety. This type of closure is usually the full width of the container and it will also provide the space for the decoration of the package, since the large area of the closure allows the designer to display most, if not all, of the desired decoration and product information on the closure. Moreover, the method of display enables the lid (closure) to be used effectively for consumer information.

The decoration for this type of packaging may be (i) an insert into or onto the lid, (ii) by direct printing of the lid itself or (iii) by moulding a label within the injection moulding during the lid manufacture (in-mould labelling). Each method has its advantages and drawbacks. Generally, with the use of an insertion onto the lid, the strength of the insert can be utilised to give additional strength to the final pack. Thus, if a cardboard insert is used, for example, with a vacuum-formed lid, then the strength, and therefore the thickness, of the plastic material can be reduced to achieve the same overall strength as that from a printed lid. Using in-mould labelling, the print effect can be enhanced by the thin plastic layer over the top of the label, thus also increasing the scuff resistance of the print.

Tubs are used for many different products, from fresh fruit through to confectionery, fats and ice creams, and other non-food products. Each product has its own specific requirements for the protection that is required from the pack. Fresh fruit, for example, does not require a hermetic seal as the air circulation within the pack allows the moisture to dissipate and prevent spoilage due to mould growth. For fats, again there is no requirement for a hermetic seal, but there is the requirement to prevent the loss of moisture. Thus, a seal is required and, even though it is not hermetic, the moisture loss is restricted both by the closure seal and by the insertion of a loose diaphragm on the top of the product. With ice creams, it is necessary not only to prevent moisture loss but also to protect the product from 'freezer burn'. It should be noted that a better seal is required here than that afforded for the fat and spread packs.

Both vacuum-formed and injection-moulded closures have similar styles of sealing in which the closure (lid) is recessed in the central portion and also clips around the outside of the container. There are, however, instances in which the central portion is not recessed but is flat across the top. This is usually done to achieve a cheaper lid as the mould tool costs would be less and the production output could be higher. Again, this is usually used for packs where the seal is primarily to hold the lid in place and not to give hermetic protection.

7.5.1 Vacuum-formed lids

In Fig. 7.24, it can be seen that the lid is recessed into the top of the container and that it forms a 'click' seal around the outside of the container. Careful control of the inner recess and the outer 'click' lip gives a superior seal than that obtained if

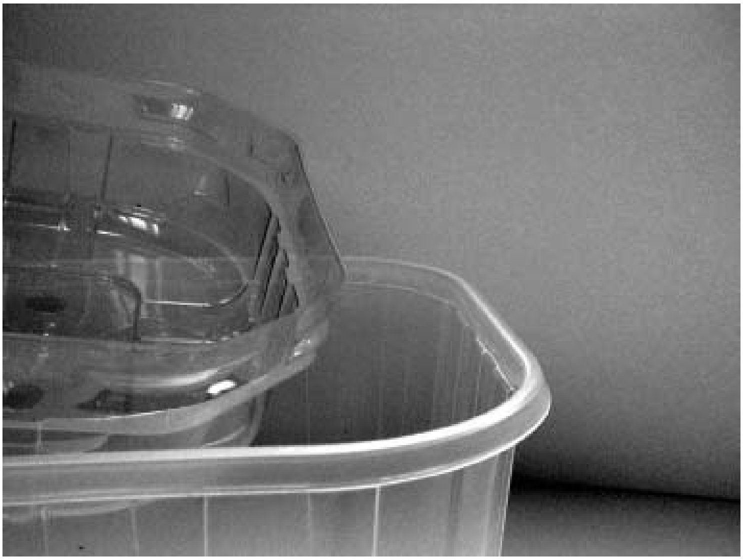


Figure 7.24 A typical vacuum-formed container with lid.

the inner recess was missing. In some of these types of lids, additional holes are provided in the lid and in the container to increase air flow for fresh produce.

7.5.2 Injection-moulded lids

With some applications, the precision required for the fit of the body of the container to the lid is such that the tolerance afforded by the vacuum-forming process are insufficient. In such circumstances, it is necessary to resort to the more costly injection moulding techniques. Injection moulding is more costly, both in the initial tooling costs and also in the production/moulding costs. Nevertheless, the finishing operations are reduced. Injection-moulded lids can also benefit from a process where the 'label' for the product is moulded into the lid itself, rather than being added as a separate label in a post-production stage. Again, 'in-mould labelling' is more expensive than a standard injection-moulded product as the production speeds tend to be lower and the cost for label inserting equipment more.

Figure 7.25 shows a typical example of an injection-moulded container and lid for a vegetable oil spread.

Figure 7.25 Injection-moulded container for a vegetable oil spread.

The lid, or closure, seals around the periphery of the container whilst being seated within the container – this allows for a more secure seal than would be provided with only one of the sealing points. Furthermore, it can be seen that within the moulding there are some indentations on the outer surface of the sealing area on either side of the corners. These are present to aid with the lid retention for repeated opening and closing.

In the cross-section image in Fig. 7.26 it can be seen that the lid seals over the outer lip of the container and also sits within the container. In this image, the lid is sitting slightly outside the container to aid the viewer with the identification of the two parts (lid and container).

Figure 7.26 Cross-section view of lid and container.

In Fig. 7.27 the injection-moulded lid shows the indentations that are moulded into the lid to aid the sealing of the lid on repeated closures in use. Although

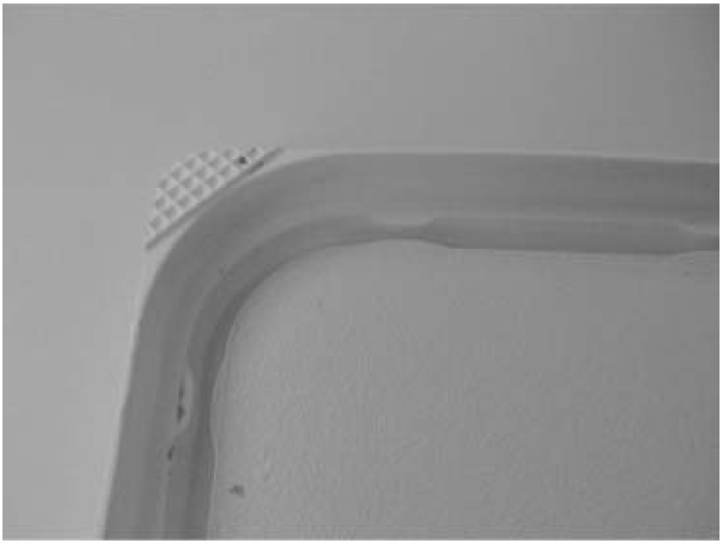


Figure 7.27 View of the injection-moulded lid.

these features are also possible with vacuum-formed lids, the precision of the injection-moulded process makes them more effective. For example, when closing the container, a definite ‘click’ can be heard, which gives the user the added confidence that the closure has been successfully completed.

7.6 Conclusions

Push-on closures are a major form of closure within the packaging industry, mainly because of their effectiveness in performing the task. Push-on closures perform a wide variety of applications and are one of the mainstay applications for closures. The wide variety of materials and processing methods used for making these closures should not be ignored by the technologists while considering a broad range of possibilities for the use of push-on closures.

Push-on closures have a double function in so far as they can be used either for the primary sealing and closing function or as a secondary sealing/containing function. Using a push-on closure as a secondary closure allows the packaging technologist to retain within the packaged product, such items as instructional and promotional leaflets, or even vital additional components for use with the product itself.

Apart from a broad range of possibilities for push-on closures in terms of use, the types of materials that can be either closed or covered by push-on closures is amongst the largest of any type of closure, and this is also true of the production methods available to technologists choosing push-on closures for their products. Therefore, when designing or considering a change to a pack, the potential and attributes of push-on closures should be considered seriously.

8 Flexible packaging closures and sealing systems

John Durston

8.1 Introduction

Flexible packaging has grown in use over the last few decades, and it is now one of the most widely used forms of packaging, particularly for food products, because of its ability to provide protection and on-shelf appeal in a highly cost-competitive way.

Flexible packaging materials, as is the case with all other types of packaging materials, are designed to protect, preserve and promote the packaged product. Today, the functionality of the package is also a key factor, but firstly, the reader may initially want to know what is meant by flexible packaging. In a market study carried out by PCI (Films Consulting Ltd) in 2003, the authors used the following definition: "the manufacture, supply and end conversion of plastic and cellulose films, aluminium foils and papers, which are used separately or in combination for primary (and some secondary) retail food and beverage packaging, plus certain specialist non-food niche sectors, such as tobacco, medical, pharmaceutical and personal care packaging" (*PCI Quarterly Bulletin*, June 2003).

In 2001, the flexible packaging industry in Europe had an estimated turnover of 7.5 billion Euros. It was growing, by value, at about 2% per annum overall, and, by volume, at 4% per annum. It therefore comprised a major segment of the European packaging market by value and by number of units of packaging produced; indeed, about one third of the total expenditure on packaging in Europe relates to flexible packaging – and approximately 80% of this is used for packaging food products.

There is a growing need for innovative and/or better performing packaging. This need is driven by a number of demographic and socio-political factors: the demand is strong for convenience packaging; easy-open/re-close packs; long life for fresh ingredients; and fewer packaging materials in use. All these needs require a major development effort, not only to select the precise materials combination, but also to determine the best type of sealant and closure system to ensure perfect results.

This chapter describes the main types of sealing systems and sealant layers in common use. It also explains the properties that can be included to improve machineability or add special features to the package. Common sealing problems are identified and the methods used to cure those problems.

8.2 Sealing layers and special additives

A package can only fulfil its primary functions of containing, preserving and protecting the packed product if the package is properly closed. This is normally achieved by sealing the packaging film to itself, either by applying a combination of heat to melt the inside surface of the film and pressure to fuse the molten surfaces together, or by the application of a cold-seal cohesive coating to the inside surface of the film. Cold-seal coated films are referred to later in this chapter.

In flexible packaging the most commonly used film for heat sealing purposes is polyethylene (PE). PE can take the form of a homopolymer polyethylene film or a polyethylene copolymer. PE film is used either as a single-web film or the film can be a component layer in a laminated structure. By using different types, grades and blends of PE, combined with multi-layer co-extrusion process technology, it is possible to tailor-make PE films against specific packaging requirements.

In many cases it is not sufficient that the sealing layer just provides sealability, since other characteristics may also be important. For example, the film usually requires a certain amount of slip to enable the film to run well on automatic packaging machinery, or a film may need to have anti-fog properties to avoid problems from condensation, etc.

For applications where the package is subjected to subsequent heat processing, such as steam sterilisation, a polypropylene sealing layer may be used, since the melting point of polyethylene is too low for the film to cope successfully with the demands of a steam sterilisation process.

This section reviews in more detail the key functional characteristics required of a successful sealing film and how these can be incorporated into the film.

8.2.1 Anti-static

During processing, most flexible packaging films, including polyethylene, will generate and retain an electrostatic charge. This can be a serious problem, particularly where these films are used to pack lightweight, free-flowing powders, since, during packing, such powders are attracted to the inner (sealing) surface of the film where they interfere with heat sealing, creating weak seals or incomplete seals that are not airtight.

An electrostatic charge on the surface of a polyethylene film can be removed in a number of ways; typically it will be carried out by means of a static eliminator on the packaging machine, or by incorporating an anti-static additive in the polyethylene film at the time of extrusion. The majority of film additives work by attracting moisture from the atmosphere to the surface of the film to disperse the static charge.

8.2.2 Anti-fog

The appearance of moist chilled products, such as fresh meat and salad, can be adversely affected by condensation forming on the inside surface of the package. The naturally low surface tension of untreated polyethylene film results in condensation forming as minute droplets; this ‘misting’ or ‘fogging’ of the film surface makes it difficult for consumers to properly view the packed product.

Where good product visibility is required, an anti-fog additive is normally added to the polyethylene at the time of extruding the film. Alternatively (or additionally), the anti-fog component can be included in an aqueous or solvent-based coating that is applied to the surface of the polyethylene film after extrusion. The effect of the anti-fog additive is to effectively raise the surface tension of the film, so that any water droplets forming as a result of condensation are easily dispersed in the form of a thin liquid film that does not interfere with the product visibility.

8.2.3 Blends

Despite the multitude of polyethylene types and grades available from the polymer producers, it is not always possible to obtain all the required properties for processing purposes or end-use performance using a single polymer resin. The film converter often finds it necessary to combine two or more grades of polyethylene polymer by physically mixing or blending the polymer resins before extruding the film in order to achieve the desired combination of properties in the eventual film. An example of this is the use of blends of linear and standard low-density polyethylene. Although easy to extrude, standard low-density polyethylene film does not have the same strength and toughness in comparison to a film of linear low-density polyethylene of equivalent thickness. However, linear low-density resins can be more difficult to run on conventional extrusion lines – by mixing, or blending, the two resins, a balance between film processing and end-use performance can be achieved. Of course, not all blends result in optimising properties: a mismatch can result in an overall loss of performance, a common difficulty being a significant increase in haze, or loss of clarity, arising from inadequate mixing or inherent incompatibility between the blend components.

8.2.4 Co-extrudates

The last 10 years has seen a significant growth in the use of co-extruded polyethylene films, particularly in added value and high technology applications. Co-extrusion is a cost-effective method of optimising the performance of a film by combining different polymers in a multi-layer structure. Co-extruded polyethylene films typically comprise two or three layers, and may be produced by a blown or cast process. A three-layer structure might consist of an outer layer (selected for its good surface properties, e.g. gloss or print receptivity); a core layer (which provides the necessary mechanical strength and toughness for the intended application), and an inner sealing layer (necessary for heat seal performance on a packaging machine).

An important benefit of the co-extrusion process is that the properties of each layer including thickness can be optimised for a specific purpose, thus, the need to compromise on performance is minimised. An important economic benefit of the co-extrusion process is that the individual layers can be only a few microns in thickness. Frequently, only a very thin layer is required for functional performance, but, in practice, it would be impossible to produce these very thin layers as single-web materials. Consequently, there are major cost benefits from the co-extrusion process particularly where expensive polymers are needed.

8.2.5 Colouring

Polyethylene is naturally colourless but, for many applications, a coloured film is desirable. Coloured films are generally produced using special colour master batches. The colour master batch comprises a polyethylene resin containing a concentrated amount of colour pigment. This is usually produced using a twin-screw extrusion process and supplied by specialist producers. The film converter will blend a small quantity of the coloured master batch into the polyethylene resin prior to extruding the film. Large quantities of white polyethylene film are used in applications such as for frozen foods. Other colours can be produced, but the use of special colours is limited by the premium associated with the higher cost of producing coloured films.

Indeed, in producing coloured films it is important to ensure that the pigment is evenly dispersed within the film. There are limits on the quantity of coloured pigment that can be added to polyethylene film without incurring problems of dispersing the pigment or affecting the mechanical properties of the film. As pigment levels are increased, it is usual to put the pigment in the core layer of a co-extruded film to avoid adversely affecting the surface characteristics of the film (e.g. surface gloss, slip).

8.2.6 Friction

For many packaging applications, it is necessary that the packaging film has good slip properties (coefficient of friction = 0.2–0.3). This is often driven by the need for efficient running on automatic form-fill-seal packaging machinery. In the case of pre-made bags, it can be difficult to open bags or pouches if the slip is insufficient.

The slip of polyethylene films can be improved through the addition of amide waxes, for example erucamide and oleamide. The required level of amide to achieve a specific coefficient of friction in the final film can be introduced by the polymer supplier, or added as a master batch to the polyethylene resin by the film processor at the time of extrusion. Following film extrusion, the amide will migrate to the surface of the film. Care is required to ensure the correct additive level, as excess amide can adversely affect a number of film properties, including film clarity, ink adhesion, bond strength in laminating and heat seal performance.

8.2.7 Gas barrier

Polyethylene films provide an excellent barrier to moisture vapour, but are not an effective barrier to gases such as oxygen, nitrogen or carbon dioxide. Many food products are sensitive to oxygen, and their shelf life can be significantly reduced unless an oxygen barrier layer is built into the structure of the packaging film; there are several ways in which this can be done. One such method is to incorporate a barrier layer by co-extruding a thin layer of ethylene vinyl alcohol as a core layer in the polyethylene sealing film. As polyethylene and ethylene vinyl alcohol have no natural chemical affinity for one another, this is usually done in the form of five-layer film. The central layer of this co-extruded film comprises ethylene vinyl alcohol, and the intermediate layers are chemically modified polyethylene copolymers that act as adhesive or tie layers to bond the ethylene vinyl alcohol to the polyethylene outer layers of the film.

An advantage of this approach is that the thickness of the barrier layer can be tailored to the needs of the product to be wrapped and the production cost minimised. A second advantage is that the barrier can be positioned close to the product, minimising the risk of migration from the packaging to the product or vice versa.

8.2.8 Hot tack

Hot tack is a term used to define the strength or peel resistance of a seal while it is still hot following heat sealing. This is an important feature in the formation of packages, especially on vertical form-fill-seal (VFFS) packaging machinery, but it can also be an issue on horizontal machinery. As packaging machine speeds have increased over the years, and as pack weights have increased, more demands are constantly being made on the packaging materials.

Increasing packing speeds often involves higher sealing temperatures on the packaging machine. This places extra demands on the packaging film. During heat sealing, the film will retain the heat from the sealing operation for several seconds, during which time the hot seal may be required to support the weight of the packed product and also cope with other stresses imposed on it as a result of the packaging operation. For example, stresses arise from the stiffness and 'memory' of many packaging film structures; these stresses tend to force the seal open as soon as the pressure from the sealing jaws is removed.

A polyethylene resin with high melt strength may be needed to provide the necessary hot-tack properties in the packing operation. With certain products (for example, liquids and finely dispersed powders), it is not uncommon for the product to contaminate the sealing area. This places additional demands on the packaging film and can dramatically reduce the effective performance of the film in terms of heat seal threshold and hot tack.

8.2.9 Low sealing temperature and short sealing time

Pressure to reduce packaging costs has resulted in a demand for increased packaging machine speeds; faster packing speeds, in turn, mean that packers have to operate with shorter sealing times; shorter sealing times put further demands on packaging materials, including the need for even lower heat-seal threshold temperatures.

The emergence of metallocene polyethylenes has provided a range of new polymers with even lower melting points and seal threshold temperatures than earlier generations of polyethylene. Additionally, the lower seal threshold of metallocene grades increases the effective seal temperature range of many co-extruded and laminated film products, making it easier for packers to run film structures such as OPP/PE without the risk of film shrinkage or burn through.

8.2.10 Heat treatment

A growing number and range of food products are subjected to heat treatment after packing. This may be done to extend the shelf life of the product, or because the product is designed to be heated by the consumer in its original package prior to consumption. When the product is packed in a flexible package, the package designer has to take into account the temperature that the package may be subjected to during heat treatment, since not all flexible packaging materials are able to withstand the temperatures that may be involved.

Heat treatment can take various forms. Typical heat treatment processes include hot filling and pasteurisation. These processes will generally involve temperatures of 70–90°C and full sterilisation in a steam retort (121–134°C, depending on the product). In addition, products that are designed for re-heating by the consumer in the original retail pack prior to consumption may be subjected to boiling (100°C) or re-heating in a microwave (above 100°C) or conventional oven (180–200°C).

The melting point of a typical low density or linear low-density polyethylene film is approximately 110–125°C. Therefore, while standard low-density and linear low-density polyethylene films are considered adequate for applications involving hot filling and pasteurisation, these films are not suitable for applications that involve steam sterilisation. In this case, it would be normal to use a polypropylene film, which is better suited to the application because of its higher melting point and greater temperature resistance. For slightly less demanding applications involving boil-in-the-bag or microwave re-heating, a medium- or high-density polyethylene film would be satisfactory, although polypropylene can also be used.

8.3 Sealing technologies

The two most used technologies for sealing of plastic materials are impulse sealing and sealing with constant heat.

8.3.1 Impulse sealing

Electricity of a certain power is led through a metal wire with a given electric resistance by means of which heat is developed. This system is primarily used for sealing on pure polyethylene; the adjustment possibilities for impulse sealing are dwell time and pressure.

8.3.2 Constant heat

With this method, heating elements are built into the sealing jaws, allowing a third adjustment possibility, that of temperature. The constant heat method is the primary system used for laminates and the system subsequently referred to in this chapter. The three adjustment possibilities enable more accurate sealing properties and stronger and tighter seals, especially on fast-running machines with a high output. In general, it can be said that to achieve a good, tight seal, the three parameters of temperature, dwell time and pressure must be balanced. Thus, if the sealing time is reduced – meaning packaging speed is increased – it is necessary to increase the pressure or the temperature to compensate.

This is illustrated in Fig. 8.1, which shows that any reduction in the time allowed for sealing has to be offset by a corresponding increase either in temperature or pressure, or both, to achieve an acceptable result. In practice, one is restricted in the degree to which these key variables can be altered, either because of the design of the packaging machinery, or constraints of the packaging film that has been selected for the application.

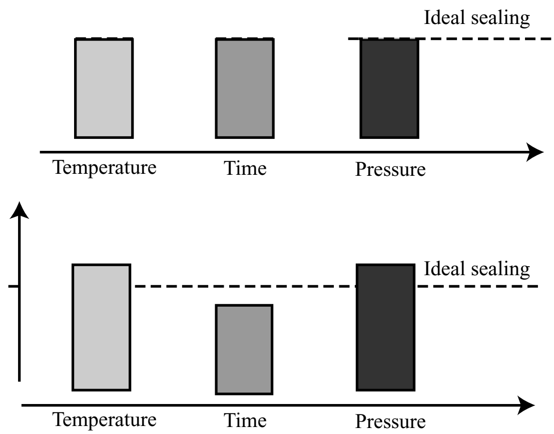


Figure 8.1 Relation showing sealing time versus temperature and pressure to increase packaging speed.

8.4 Types of seal

This section deals with the main types of seal that can be created using flexible packaging films. Fin sealing and lap sealing deal with the geometrical layout of the film at the time the package is formed. Additionally, for many applications, while it is desirable to create strong weld seals that will stand up to maximum physical abuse, it is important to acknowledge the growing pressure for packaging to be consumer friendly – in other words packaging should be designed to be easy to open and, if necessary, to re-close.

8.4.1 Fin seal

A fin seal is formed when the inside surface of the film is sealed against itself. This is commonly used on horizontal or vertical form-fill and seal machines.

8.4.2 Lap seal

A lap seal is formed when the inside surface of the film is sealed against the opposite (outside) surface of the film. This method is often used to form the longitudinal or back seal of a pack made on a vertical form-fill-seal machine.

Lap sealing offers certain advantages on vertical form-fill-seal packs, and for over-wrapping applications, material usage is marginally reduced; this can make for easier end sealing because the maximum number of film layers in the cross seal is reduced and it can result in a tidier looking package.

Lap sealing has also been used in the development of new pack styles with additional features. Amcor's 'EasyPack'®, with easy opening and re-closing, is such an example (see also Section 8.4.3 and Fig. 8.2).

Figure 8.2 Lap sealing showing easy opening and re-closing.

Film structures may need to be designed specifically to allow for A/B sealing (lap seal). Symmetrical structures, in which the outer and inner layers are both polyethylene, will lap seal without the need for a special film formulation. However, the use of a non-symmetrical film may require the inner polyethylene film to be re-formulated to seal to a different material on the outside of the pack, e.g. a co-extruded oriented polypropylene film (OPP).

Film producers have successfully developed polyethylene films specifically for this purpose; these not only provide effective sealing, but are also capable of producing fully gas-tight seals for modified atmosphere packaging, gas flushing and barrier applications.

Figure 8.3 illustrates various sealing and packaging types.

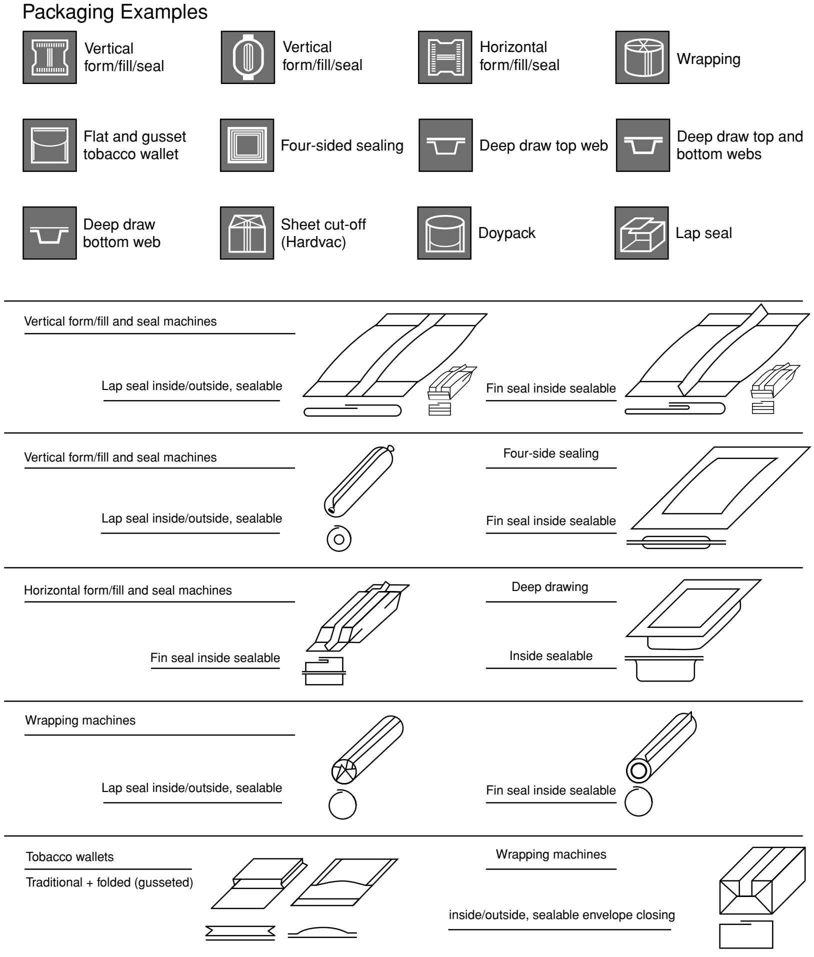


Figure 8.3 Packaging examples.

8.4.3 Peelable seals

There is a growing demand from consumers for flexible packs that are easy to open. One means of providing easy-opening flexible packaging is to create packs with seals that are easily peeled open by hand. Several factors have to be considered in designing an easy peel system: the strength of the seal is critically important; a seal that is too weak may fail to protect the contents of the pack by opening prematurely; a seal that is too strong may not meet the expectations of all consumers. Having determined the appropriate strength of the seal for a specific application, it is desirable that the strength of the seal is maintained at this optimum value over the widest possible range of sealing conditions (pressure, temperature and time) that are likely to be encountered during the formation of the pack on the packaging machine.

There are two different peelable seal mechanisms. A burst peel requires a multi-layer co-extruded polyethylene film and is created by breaking the inner sealing layer of the film, with subsequent de-lamination occurring between this and the adjacent layer in the co-extruded film structure. This type of peel seal is often used for cereal packs.

The second mechanism involves blending two or more polymers. Special blends that provide controlled peel strength have been developed. Typically, these blends contain components to modify the way in which the polymer chains interact when sealed. Peeling occurs within the seal weld or if these films are sealed to dissimilar materials at the interface between the two materials, for example, in tray lidding applications.

To further improve convenience for the consumer, a pack that can be opened and re-closed is often desirable. For many years, the main solution has been to use peelable polyethylene, as the sealing medium and recloseability has been achieved by inserting a zipper in the pack, or by using a sticky tape or label.

Two recent developments by Amcor offer new possibilities. The Amcor 'Easy-Pack' is used on vertical and horizontal form-fill-seal machines. The longitudinal lap seal can be peeled open to gain access to the product. Re-closeability is obtained by means of a hot-melt stripe, or alternatively, a tape strip applied on the machine. One of the benefits of this system, from a packaging point of view, is that there is no reduction in packing line speed, compared with a standard fusion-sealed pack.

The Amcor 'ReClose'® system was developed primarily for use on deep draw machines. The top web is a laminate consisting of a fusion, sealable polyethylene with a very low tear strength, laminated with a special hot melt to one or more outer layers of film, which provide barrier and/or printability. The top-web seals to the base web and, when peeled open, the polyethylene layer fractures to reveal the sticky hot melt that enables the pack to be re-closed. For ease of re-closeability, a semi-rigid base web should be used.

8.5 Packaging machine

Flexible packaging machinery comes in a wide variety of shapes and sizes. Many of the machines offer differing functionalities and special features that can be applied to the finished pack. However, despite the apparent differences, there are a few major principles on which most of these machines are based. This section describes the main types of packaging machinery used to create flexible packs and the basic principles on which these machines operate.

8.5.1 VFFS (vertical form-fill-seal, also called trans wrap)

The principle of a trans wrap machine is that the packaging material, which is reel fed, is pulled over a form shoulder by either moving cross-seal jaws or draw-off belts; the packaging material is then formed to a tube around the filling tube. During this action, the vertical seal and the cross seals are made; at the same time the product is fed down the filling tube. Between the cross-seal jaws, a knife is mounted, and this separates the packs. The vertical seal can be made as a fin seal or a lap seal.

Figure 8.4 illustrates a schematic drawing of the trans-wrap system.

Figure 8.5 is a typical form fill seal machine manufactured by Rovema.

8.5.2 Sealing problems and trouble shooting on trans-wrap machines

Seal failure can be caused by a number of factors; these factors may relate to the choice of packaging material for the application or the packaging conditions set on the packaging machine. Proper control of seal temperature, seal pressure and dwell time is critically important in delivering effective sealing and good packaging machine performance. Table 8.1 outlines potential problems with trans-wrap machines.

8.5.3 HFFS (horizontal form-fill-seal, also called flow pack)

The principle of a flow-pack machine is that a flat film in a forming box is formed into the shape of a tube, after which a set of rotating sealing wheels makes a length seal (fin seal). The sealing wheels transport the film through the machine. The product, which has been placed on a conveyor belt, runs into the forming box and into the tube and continues on to a pair of cross-sealing jaws, which make the end seals on the packs. End sealing is most commonly done using either rotating jaws or intermittent, reciprocating jaws, which move forward one pack length with the film while it is being sealed, open and then return to their start position to make the next end seal. A cutting knife is located between the two sets of sealing jaws to separate adjacent packs.

Figure 8.6 shows a schematic drawing of the flow-pack system.

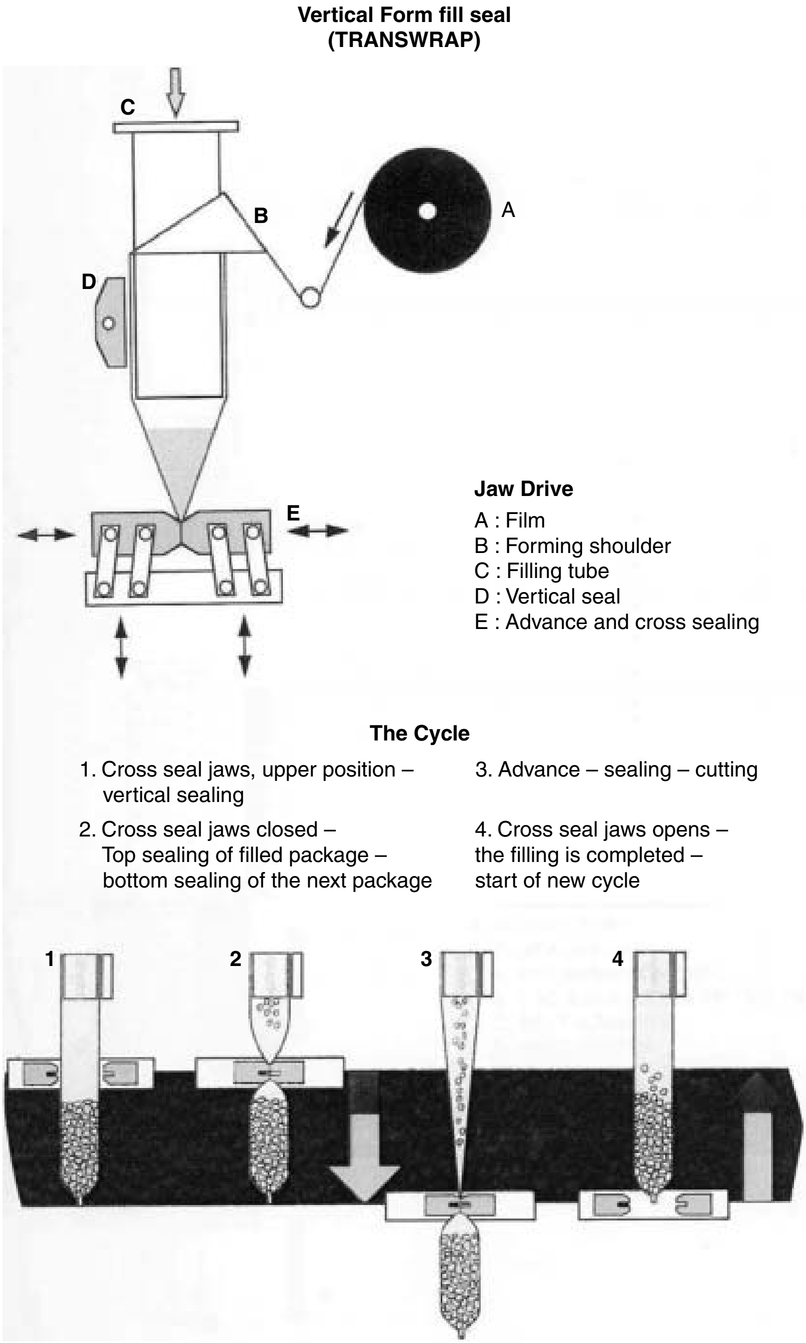


Figure 8.4 A schematic drawing of the trans-wrap system.

Figure 8.5 A typical vertical form fill seal machine manufactured by Rovema.

The rotating sealing system gives a relatively short sealing time, which is why it is necessary to have a high temperature to give a good seal. Intermittent sealing jaws give a longer sealing time, and therefore work with lower temperatures. In the area where the longitudinal and cross seals are superimposed on one another, it is necessary to seal through a double layer of film, thereby putting heavy demands on the sealing process. Therefore, it is important that the sealing jaws, which are normally profiled, are kept clean from melted polyethylene and product debris. Furthermore, it is essential to ensure that the jaws are parallel and that the sealing pressure is the same all over. A quite simple control can be executed by placing a piece of paper between the sealing jaws, activating the sealing and checking that the pattern of the jaws is equal and the profiles are centred. Because these machines are often run at a high speed, it is necessary to use high sealing temperatures, but it is still important to ensure that the recommended maximum temperature for the film is not exceeded. If the temperature of the sealing jaws is too high, the outside surface of the film may stick to the jaws, resulting in poor seals, low seal strength and even leaking packs. Often, packs are gas flushed and the original atmosphere is substituted with another atmosphere. By removing the oxygen from the atmosphere around the packed product, and substituting with a gas, such as nitrogen or carbon dioxide, it is possible to ensure longer shelf life for the product.

Table 8.1 Summary of potential problems with trans-wrap machines

Problem	Diagnosis	Solution
Product in sealing area	Filling time not synchronised	Adjust timing on machine
	Too much gas used for flushing	Reduce gas flow
	Excessive static in packaging film	Fit static eliminator device
	Bag length too short	Increase cut-off
Film bunches on fill tube	Slip on inside film layer too high	Apply PTFE tape to tube
	Film not sufficiently rigid	Use thicker film
	Film shrinking on filling tube	Reduce back seal temperature
Film moves out of register	PEC requires re-setting	Recalibrate
	Eye-mark weak or too small	Re-design or increase size
	Brake tension too high	Reduce tension
	Film wandering	Check tension on machine
Film does not feed evenly	Draw belts are worn	Replace draw belts
	Belt pressure is uneven	Readjust belts
	PTFE tape on fill tube is worn	Replace tape
Seals open while still hot	Insufficient hot tack of seal layer	Re-formulate the seal layer
	Filling time not synchronised	Re-adjust the filling machine
	Seal jaws out of alignment	Re-adjust seal jaws
Uneven cross seals	Seal jaws not parallel	Re-adjust seal jaw setting
	Dirty or contaminated seal jaws	Clean seal jaws
	Damaged seal jaws (burrs/nicks)	Repair or replace seal jaws
Weak, or no cross seals	Defective heating element	Repair/replace element
	Defective thermostat	Repair/replace thermostat
	Excessive/poorly directed cooling	Re-adjust/re-direct cooling air
Film creasing in pack	Incorrect angle of forming shoulder	Normal angle = 68°
Packs do not separate	Worn/defective cutting knife	Replace/re-adjust/sharpen knife
	Incorrect timing	Re-adjust timing

8.5.4 Deep drawing

On a deep-drawing machine, packs are produced from two separate webs of film: a base web and a top web. The base web is conveyed through the machine by means of chains with grippers and passes first a forming station where it is heated, and then is formed into a given shape by means of compressed air or vacuum, or a combination of both.

Figure 8.7 provides a schematic drawing of the deep draw system.

In the case of semi-rigid laminates, plugs are also used to facilitate the forming process and to provide better dispersion of the material. The depth of the pockets

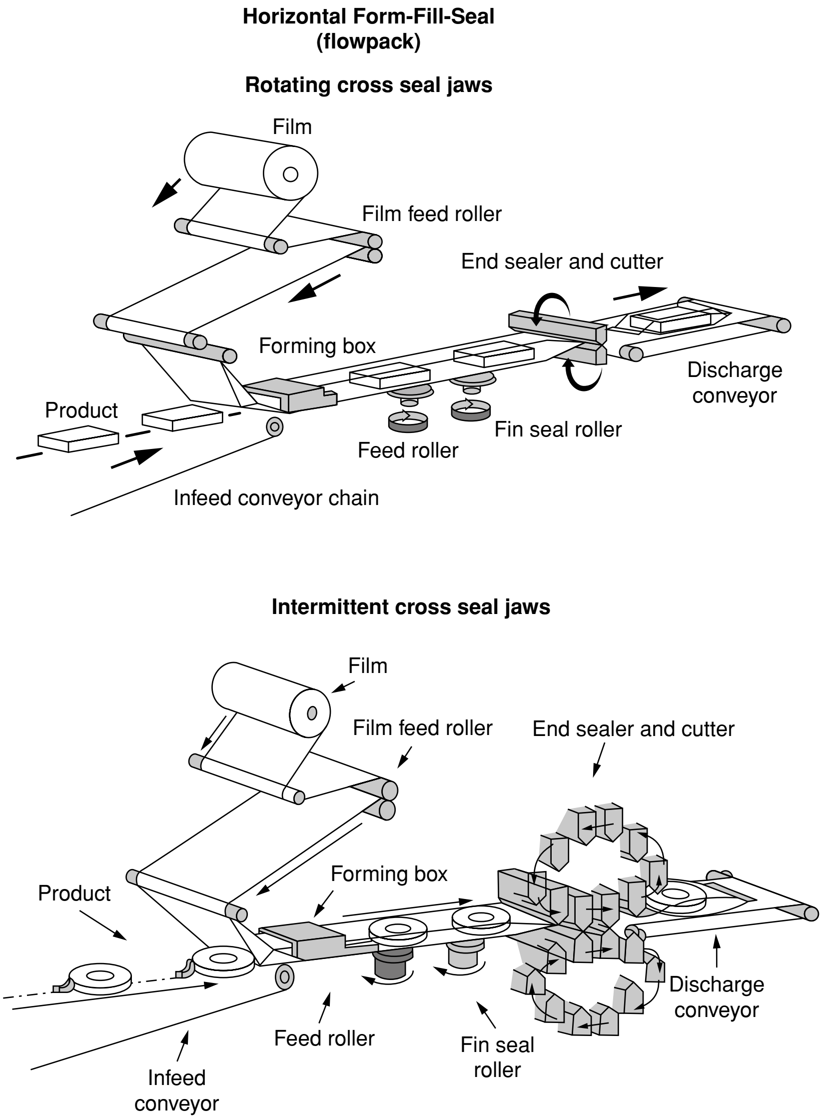


Figure 8.6 A schematic drawing of the flow-pack system.

is adjustable to fit the height of the product, so the pack fits the product. After the forming station, the laminate passes the filling station where the products are placed in the deep-drawn pockets. From here, it continues to the vacuum and sealing station to which the top web is also led.

After the vacuum station and eventual gas filling, the top web is sealed on to the base web by means of a profiled heat seal platen. Finally, the laminate passes

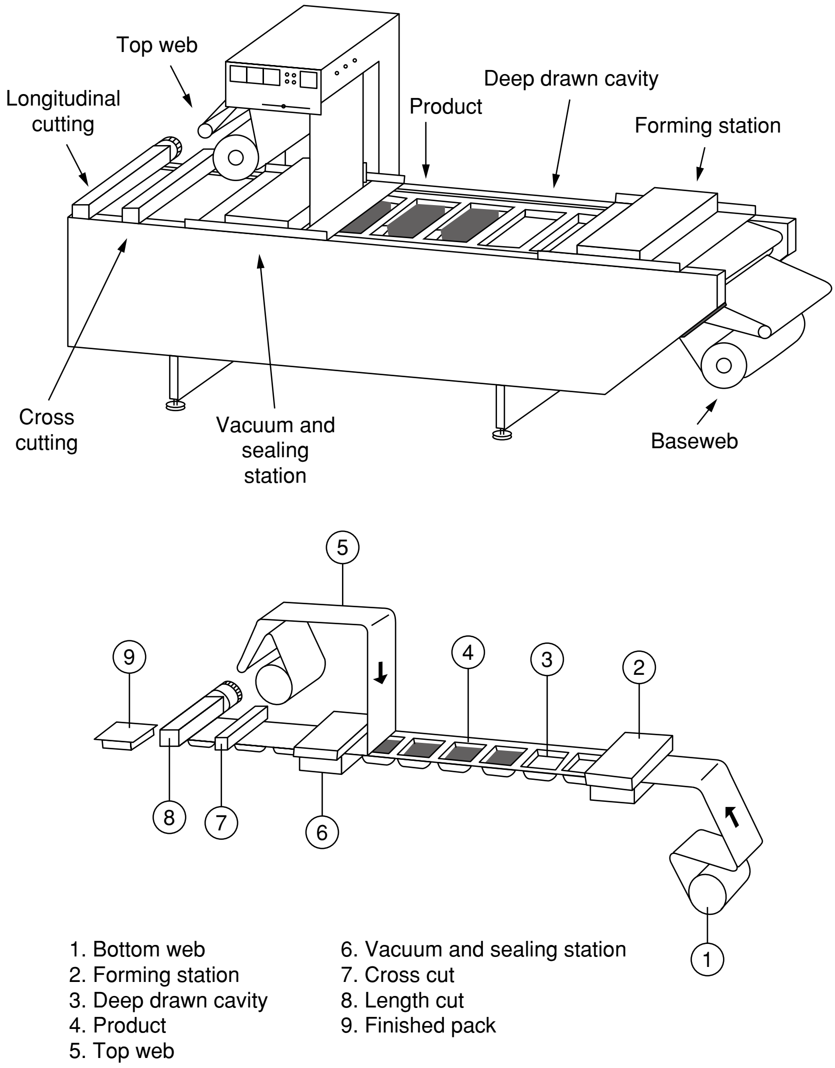


Figure 8.7 A schematic drawing of the deep draw system.

a cross-cutting section and a length cutting section where the packs are separated. For semi-rigid laminates it is necessary to have a punch unit or something similar, to separate the packs.

Figures 8.8–8.10 outline the principles of forming, including the use of plug assistance, evacuation and sealing. Figure 8.11 illustrates problems that can result in forming flexible and semi-rigid films if the position of the heating plate relative to the web is not correct at the time forming takes place.

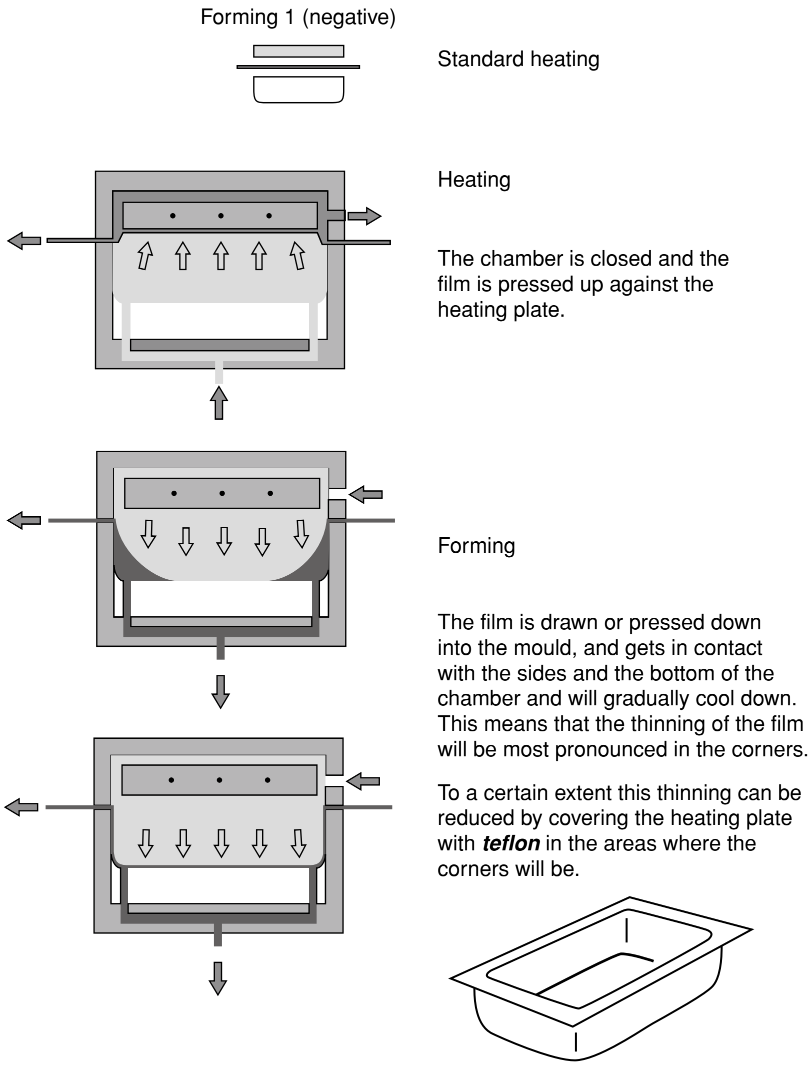


Figure 8.8 Forming (negative).

8.5.5 Sheet cut-off

There are different types of sheet cut-off machines (vertical and horizontal) but the principle is that the machine cuts off a sheet of the packaging material, folds it around a mandrel, makes a back seal and closes the bottom. The pack is then raised into an upright position, filled and partly top sealed, before being sent through a vacuum chamber, where air is evacuated from the pack and the pack is top sealed.

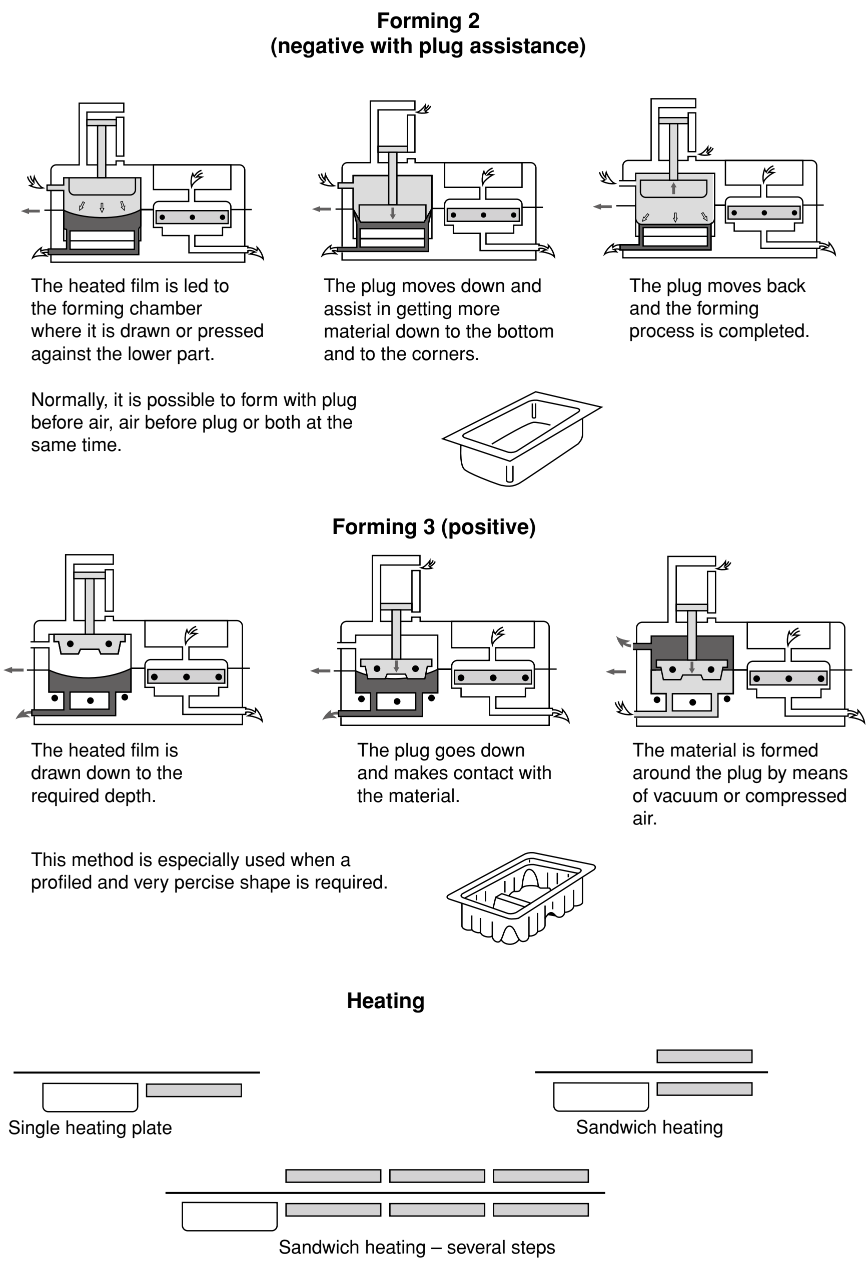


Figure 8.9 Forming (negative with plug assistance and positive).

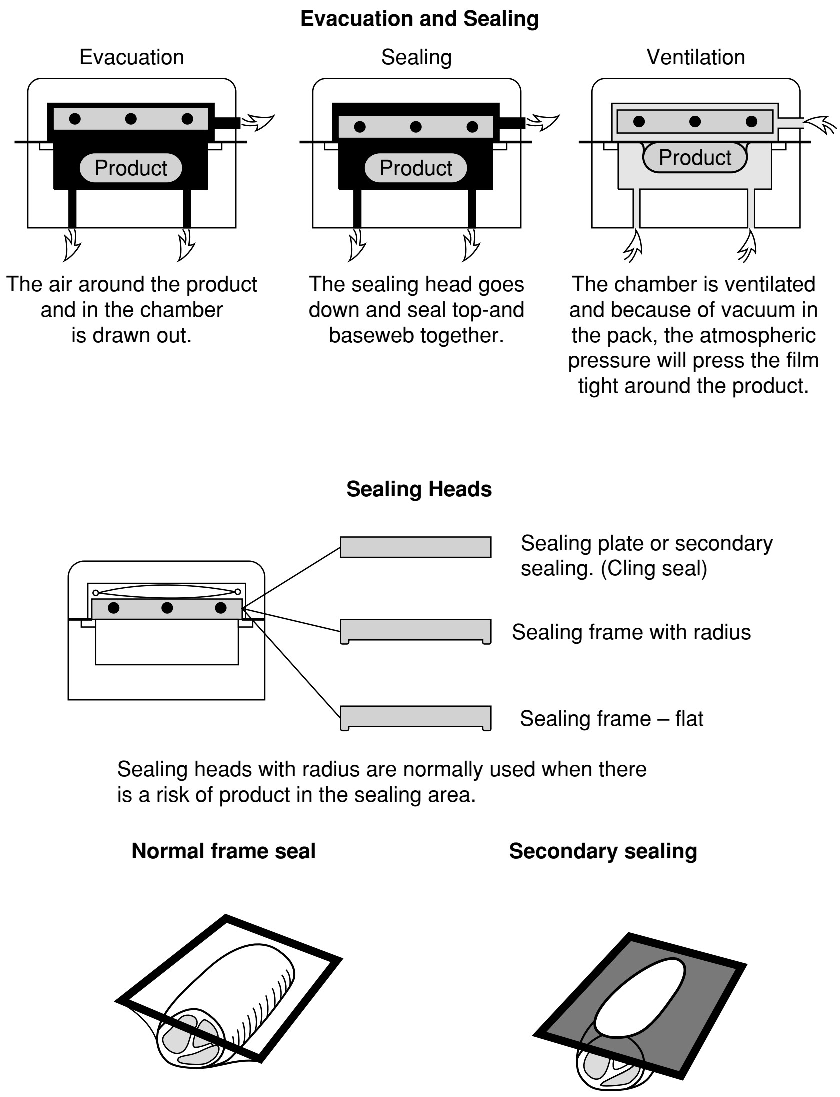


Figure 8.10 Forming (evacuation and sealing).

The packs produced on sheet cut-off machines can be single packs, in which only one web of laminated film is used to wrap the product, or double packs, with a printed paper, laminated film or carton formed around the inner laminate wrapping as part of the packaging process. This system is also called ‘hard-vac’ and is used for packaging of ground coffee, dry yeast, milk powder and other powder products.

Figures 8.12 and 8.13 indicate the principles of sheet cut-off.

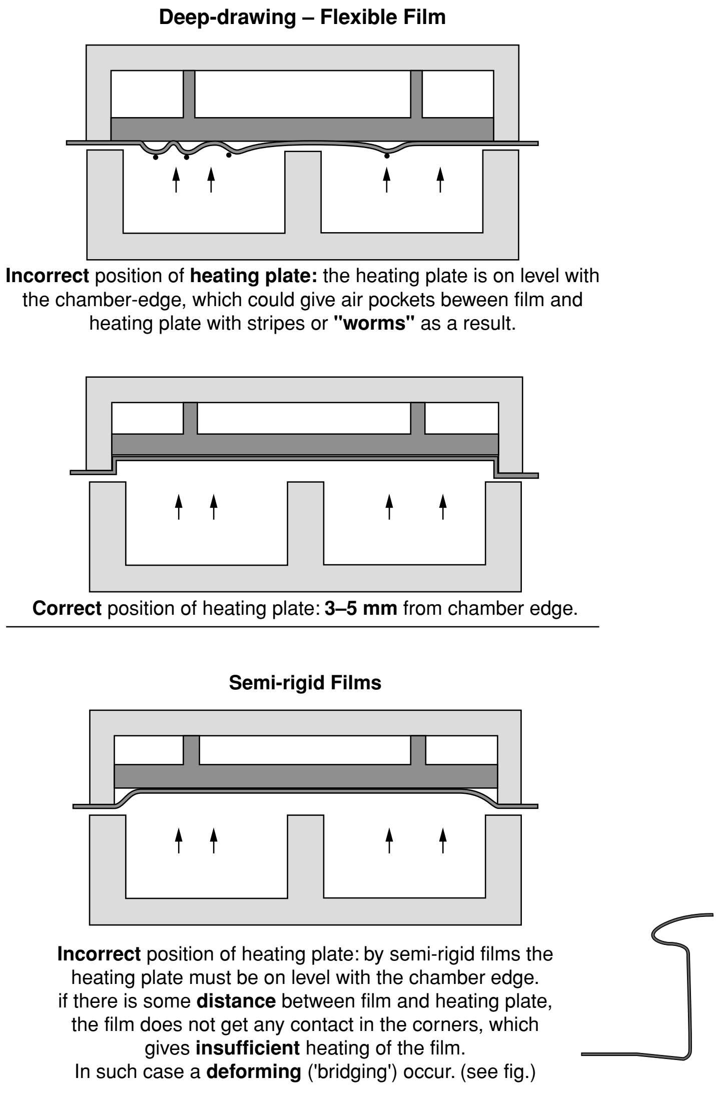


Figure 8.11 Positioning of heat plates and problems at the time forming.

8.5.6 Four-side seal

This system is used for a number of applications, such as liquids, powders and spices – products that may all be stored in very small packs. The system produces a rather simple pack, but has the advantage of being able to run in multiple lanes, thus enhancing the output.

Figure 8.14 illustrates the principle of four-side sealing.

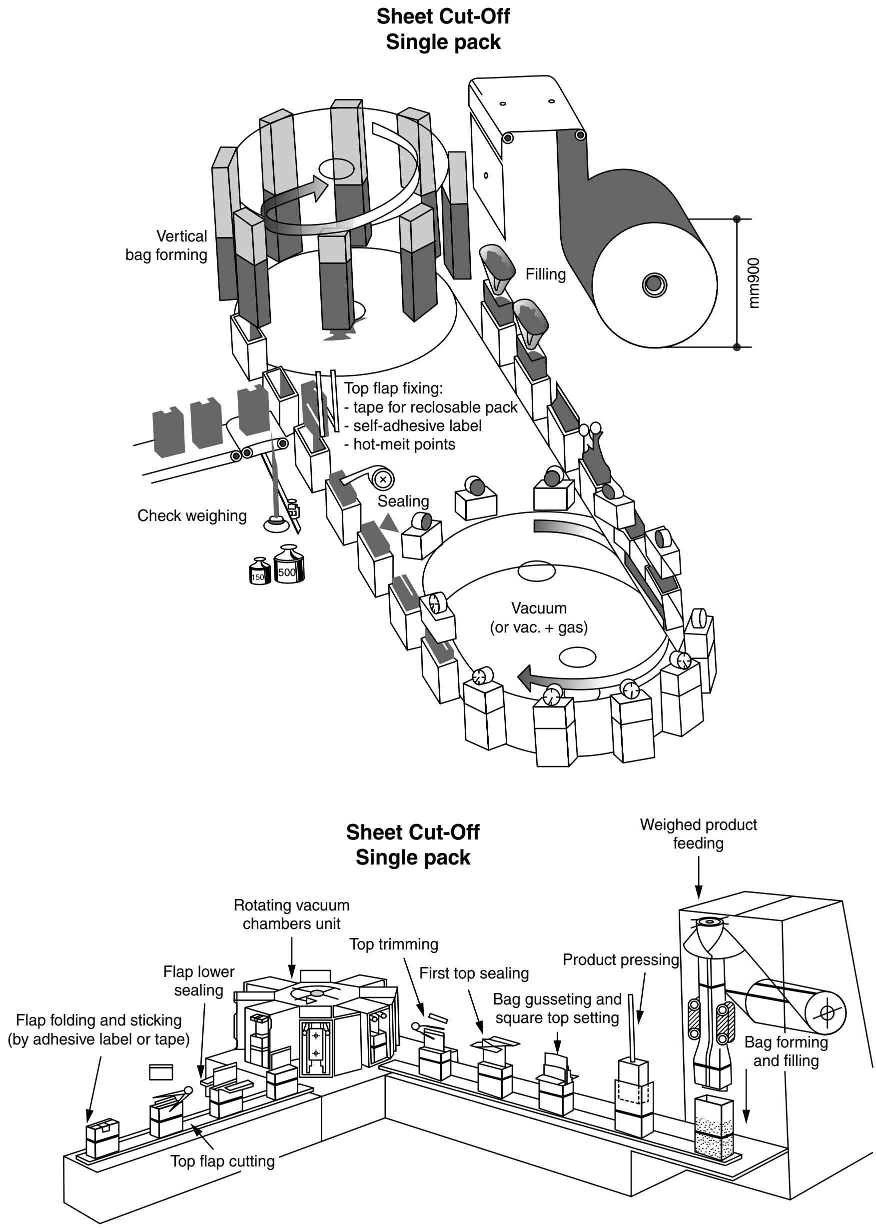


Figure 8.12 Principles of sheet cut-off (single pack).

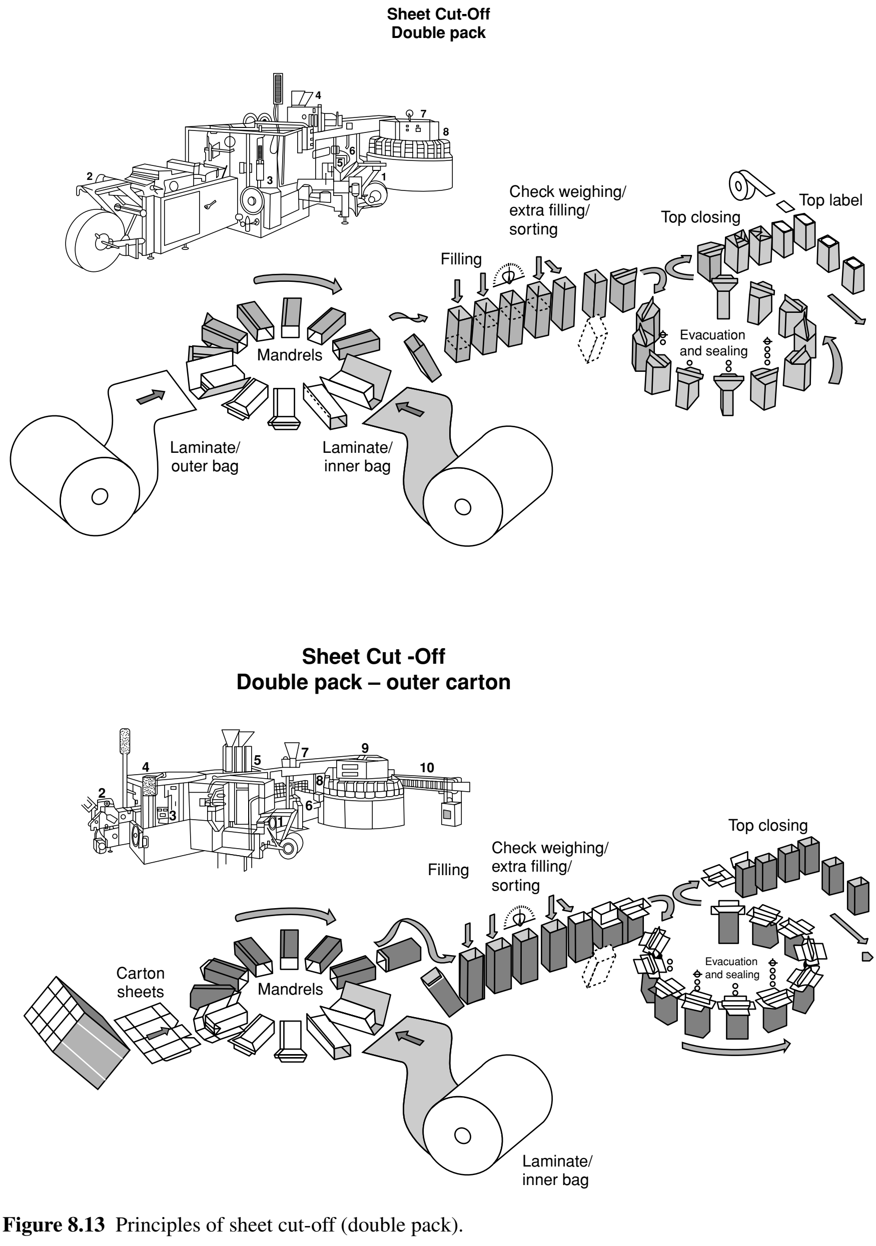
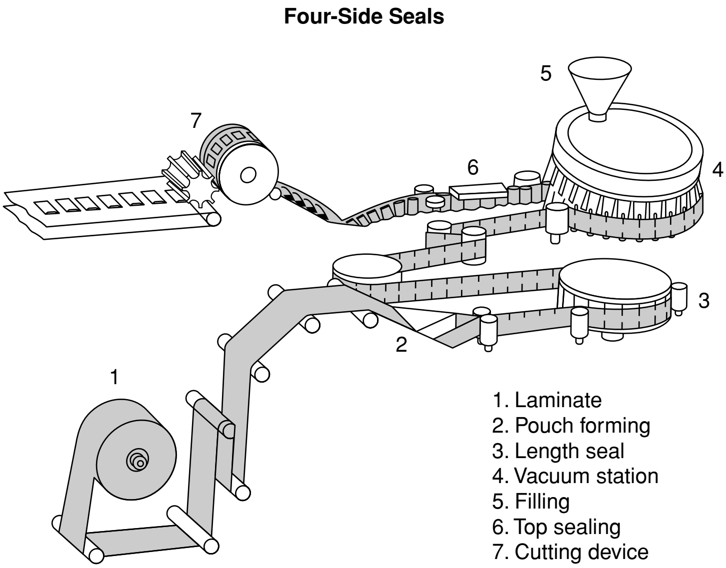


Figure 8.13 Principles of sheet cut-off (double pack).



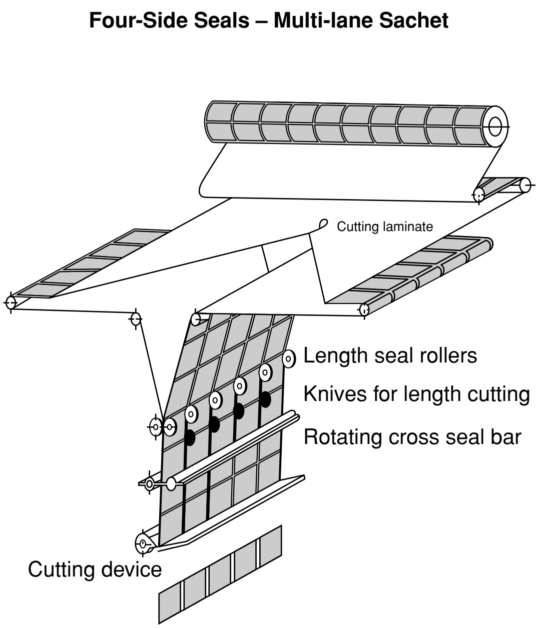


Figure 8.14 Principle of four-side sealing.

8.6 Sealing problems

There can be many causes of sealing problems and these can occur on any of the different types of packaging machines that have been described in this chapter. Some of the most common are

- Incorrect adjustment of seal time, temperature or pressure
- An incorrectly mounted reel so that the sealing layer is in contact with a heated seal jaw
- A film with incorrect hot tack causing the seal to peel open while still hot
- Film webs with sealing layers that are incompatible for sealing
- Contamination of the seal area with fat, moisture or other components from the product
- Misaligned heat seal frames. Large seal platens especially may become misaligned over time. Alignment must therefore be checked regularly
- Damaged or worn sealing elements including missing teflon tape or presence of burrs or nicks
- Damaged or worn silicone rubber gaskets
- Leaking diaphragms
- Molten polyethylene or product debris on heat seal jaws
- Folds or creases in the pack. Web tension and film transport mechanism is often the cause of film creasing

In order to prevent defects and problems, it is very important to carry out regular maintenance checks on the machines. How often these checks must be made depends on how much the machine is running and what kind of products are packed (some products contaminate the equipment more than others). After having determined these routines, the next step is to ensure that both the machine operators and the maintenance staff understand the importance of carrying out these checks at the appointed time. Good maintenance will help ensure consistent production performance and good quality packs; it will reduce interruptions to production and avoid the need for re-packing.

8.7 Pattern cold seal

This chapter has dealt with heat sealing in detail, but for specific applications in flexible packaging an alternative to heat sealing is being used, entitled ‘cold seal’. This technology requires only mechanical pressure to bond two layers together, without any heat being required. Sealing at room temperature, excellent seal integrity and a wider variety of substrates are the main advantages over heat-seal.

In the case of heat sealing during packaging line downtime, heat from the sealing jaws results in significant product damage and high reject rates. Cold seal has therefore been particularly favoured for packing heat-sensitive products such as chocolate, chocolate-coated biscuits and ice cream.

The main applications for cold sealing are in horizontal-form-fill-seal (flow-wrap) bar lines and over-wraps, although there is some use of cold sealing in vertical-form-fill-seal packaging as well. Cold seal is much less sensitive to the sealing dwell time and is more tolerant to variations in packaging line speed.

Cold-seal technology is based on a coating technique. A water-based emulsion is printed onto a web substrate by means of an engraved gravure cylinder. The key component of the emulsion is natural rubber latex, which provides the cohesive features. These coatings stick preferentially to each other, and almost to no other surfaces. Other ingredients in natural latexes are water, ammonia, surfactants, anti-oxidants, anti-foam agents, biocides and an acrylic component. The latter is present to aid adhesion to the coated surface. In the wet state, cold seal has a shelf life that is limited to six months. It must be stored away from frost and heat. After printing, a shelf life of at least six months is guaranteed. Excessive ageing allows physical, chemical and biological degradation to occur and leads to loss of seal force and development of odours. Under 0°C, an irreversible loss of sealing ability occurs. After sealing, cold-seal packaging keeps it seal integrity in a freezer (e.g. ice cream sticks).

Typical cold-seal coated film constructions are shown in Table 8.2.

Table 8.2 Typical single-web cold-seal coated film construction

Single-web cold-seal coated film construction	Cold-seal coated laminate construction
Release lacquer	Release film
Printing inks	Printing inks
	Laminating adhesive
Substrate	Substrate
Cold seal in pattern	Cold seal in pattern

Release lacquer is applied to the printed surface to allow easy unwinding (low cling) of a reel; the release lacquer consists of polyamide resin. Alternatively, a release film can be laminated over the print; this would usually be a low surface tension plain oriented polypropylene film. Typical substrates are: white pearlised polypropylene, glassine paper, transparent and metallised polypropylene, as well as metallised polyester. The cold-seal pattern provides a sealing medium in the seal areas only (fin seal and cross seal). The central area, where the content is in contact with the wrapper, is free from cold seal in order to minimise the direct contact between cold seal and food and to reduce the cost of the package. Coating weights range from 2 to 6 g/m^2, depending on the application. Typical seal strengths are 5 N/30 mm. Apart from the seal force, as measured after flat sealing and pulling in a tensile tester, a certain coating mass must be present to ensure seal integrity in the pack folds and edges.

Frequently encountered cold-seal issues are:

- Foaming in the gravure press
- Formation of lumps as a result of high shear conditions between gravure cylinder and doctor blade

- Quality variations due to seasonal fluctuations in rubber latex (natural product)
- Lack of sealing force
- Scumming (appearance of a cold-seal ghost in the food contact area)
- Mis-positioning of cold-seal pattern versus the printing
- Smell (residual ammonia or other)
- Blocking upon unwinding reels: transfer of cold seal to the release side or damage to the printed side

In recent years a synthetic version of cold seal has been developed, which has given excellent converting and sealing characteristics. It also eliminates the odour of natural latex.

8.8 Conclusion

Sealing methods have not changed fundamentally for many years but improvements to the base materials have overcome many of the problems and pitfalls described in this chapter.

In earlier years, material development was somewhat haphazard, and based largely on trial and error. In recent times, significantly more science is brought to bear on material performance; consequently, the results are much more predictable. Variations in the packing operation can be accommodated by more tolerant materials and better packing machine design. The machinery used on the packing line is much more automated than earlier, which has eliminated the scope for human error.

Acknowledgements

The author thanks John Fairweather, B.Sc., who acted as technical advisor for this chapter.

9 Child resistance, tamper evidence and openability

Nigel Theobald

9.1 Introduction

There is a need to emphasise that a growing list of consumer products *must* mandatorily have child-resistant closures (CRCs). These products include pharmaceuticals, bleaches and some aromatic products that can be inappropriately used to produce a 'high' when sniffed. Many countries have differing laws on the application of CRCs to products and also to the testing of the suitability of a closure design to be classified as a CRC. There are three main standards in existence at the moment: European Union (EU), the United States and Japan. These are all under review, with the intent being to harmonise the requirements and form a global standard for worldwide application. However, this, as is the case with all international legislation, will inevitably take many years to complete. Within the EU, the standards are being modified from the previously accepted method of testing, using a panel of children, to that of a set of mechanical tests. The actual time scale for this to take place is still being considered. Undoubtedly, CRCs will become more important as time progresses and the costs of non-compliance escalate. Health authorities in many countries are facing escalating costs of treatment for injuries sustained by product misuse or abuse (and are consequently becoming more determined to find ways of reducing their costs in this area); adding products to the list of those requiring CRCs is one way of achieving this cost reduction.

There is no doubt that the need to consider the tripartite aspects of child resistance, tamper evidence and openability are central to any subject of the package closure system. The security for both packaging user and supplier are becoming increasingly important; the supplier needs to assure the consumer that the product is safe and has not been tampered with during its journey through the supply chain to the eventual consumer. As product-packaging security systems are developed, it is also essential that the consumer can recognise these requirements and see that they have not been breached before purchase. It is highly frustrating for the consumer to discover a tampered packed product. This frustration is not directed at the tamperer, but at the supplier who did not ensure product safety.

With a growing and ageing population, the ease with which packaging can be opened is becoming much more of an issue, as it does have an impact on an individual's quality of life. The disabilities that invariably accompany age, such as loss of visual acuity, arthritic joints, loss of strength, and in particular, lack of torque or grip, create a different perspective on the needs of the package to perform correctly in the eyes of the consumer.

Child resistance to openability of the pack is now legal in many countries on certain types of products; although the latter will vary from country to country, they generally include pharmaceuticals, household bleaches and cleaners, as well as solvent products. The list is likely to increase with time, as more abuses of product become apparent and the perceived dangers of inappropriate use become evident. Child resistance and openability are sometimes seen as counter operative to each other. Each of the items identified in this list needs to be considered and the best attributes of each taken into account when designing the closure systems. Although it may appear to be unusual, when the closure (opening) systems are being analysed, one also needs to consider how to stop people opening the containers – the occasionally fatal consequences of accidents with openability are outlined in more detail in Chapter 2 of this book.

9.2 Child resistance

The first question that one might pose is 'what is child resistance?' If you were to ask a number of people this question, you would, certainly, receive a wide range of answers. The British Standard (BS6652) states that child-resistant packaging is: 'Packaging designed and constructed to be difficult for young children to open within a reasonable time and that is not difficult for adults to use properly'. The important terms here are: *designed* and *constructed* (thus, the consideration for child resistance must be not only designed into the pack but also must be constructed to achieve the result); *Young children* (whilst in the definition there is no mention of what is meant by young children there is an in-built logic that the resistance is for those children who are unable to realise the potential consequences of taking the product as well as those who have a natural inquisitive mind); *Adults* (once more, this term is not defined and there is no age limit specified in the definition or any mention of those with a disability) and *use properly* (another interesting idea: There is no mention here of only being able to open the pack but to use the product properly. Thus the requirement is not only to be able to open it but also to use it in the manner intended). See also Fig. 9.1.

Child resistance on packaging items for many products are mandatory in European law (and in all EU Member countries), the United States, Japan and a number of other countries throughout the world. Many countries that do not have specific national legislation are nonetheless looking to the major countries in the world and following their best practices. There is also a move to harmonise legislation in the major areas (EU, the United States and Japan) to form a common harmonised set of legislation that will be applicable throughout these major territories.

The principle that had been adopted within the EU was of testing each pack on a panel of children (and adults) to see how often the children could open the packs without any explanation of how to open them. The adults were also asked to open the packs to see if they were able to do so without explanation. This approach,

Figure 9.1 Closures for child resistance.

however, resulted, in at least some children being able to open packs even if they are rated as child resistant. Despite the additional requirement that the children should not be exposed to the test before, the number of children being exposed to a child-resistance test is continuously increasing, as the number of tests performed increases. This increases the number of children who have made some attempt to open the pack, and thus there is a possibility that they will try again. It is therefore necessary to have some alternative method of assessment to minimise child exposure to such tests.

A fuller explanation of the tests and their application is given in Chapter 2 of this book. A list of some of the relevant standards is also given at the end of this chapter. It should be noted that the standards mentioned are the major standards for the main product areas. Specialised areas may require adherence to different standards (such as explosive products, etc.) and the reader should be aware that these standards, which may be mandatory in different countries and applications, are not covered in any detail here.

The discipline of child resistance is changing, from the testing with a group of children (to achieve a result that they *substantially* cannot open the packs) and adults (to show that they *can* open the packs), to testing by a fixed mechanical testing procedure. It is likely that the testing regime will also change from that of each pack needing to be tested to one of 'type' approval. There is also one international standard from the International Standards Organisation (ISO), which represents some 140 countries throughout the world in standard setting. This standard is ISO 8317:1989 and is for reclosable packages. Thus the picture, as with all packaging items, is one of continual movement. At present, there are several types of CRCs available in the market and these are discussed in detail below.

9.2.1 Non-reclosable single dose

The packs for pharmaceutical products that are single dose and non-reclosable have traditionally been considered to be child resistant. These packs are normally of the blister pack type. However, even here there is a provision that the material that is used for the construction of the pack must be opaque. It is therefore considered that children will not be able to see the contents and thus not be prepared to open the pack to such an extent that they will be able to ingest sufficient amount of the product that may cause any permanent harm to them.

In the UK the data provided by the National Poisons Unit of the Health Service show that the risk assessment for opaque blister packs is low compared to those of non-opaque (transparent) blisters and of reclosable multi-dose packs. Although this is valid only for the United Kingdom, there is no reason to suspect that children elsewhere in the world would be affected in a different way. The main problem is that if children can see the product through the blister, there is a greater chance that they will open the pack and risk poisoning themselves. Many of the tablets that are in the blister packs are brightly coloured and therefore attractive to children, who may become excited about the ‘sweets’ that are being dangled in front of them.

Table 9.1 Accidental poisoning of children – accident risk assessment

Re-closable packs	1.2
Re-closable CRC	0.6
Blister	1.9
Opaque blister	0.4
Strip pack	0.1

Table 9.1 shows that the opaque blister and strip packs are considered to be the safest of the pack varieties. The majority of the blister packs in the market are of the push-through type, where the tablets (that are usually contained in the blister) or solid dose product are pushed through the ‘foil’ sealing of the blister to gain access to the product. This allows also for the ‘foil’ to be securely heat sealed to the base web of the blister around each pocket. Where the product is not a solid dose, or the solid dose is friable enough to be broken when pushed through the blister, a tear-type blister foil is required. In such cases, it is essential that the foil is perforated between each pocket so that only one pocket is opened at any one time. Failure of the perforation would allow more pockets to be opened and risk an accidental overdose (and this would clearly not be considered child resistant). I have used the term ‘foil’ for the sake of convenience but the lidding material could be of an aluminium foil or of differing substrates of metalised materials or paper-based products. The main criteria for the lidding material is that it is capable of maintaining the pack integrity and shelf life of the product, and also capable of being ruptured without undue force being required.

9.2.2 *Strip packs*

As with blister packs, the single dose form of packaging is considered to be inherently child resistant. The criteria are that the material should be opaque, and that it is only possible to open one cell at a time. Many strip packs include, within their construction, an easy-open notch to enable the user to open the pack without recourse to any mechanical opening device. There are also materials available that will tear easily in one direction, but are difficult to tear in the cross direction. This allows the packer to fabricate a pack that will perhaps tear across the pack (when in a single strip), but not down the pack, thus ensuring that only one pocket can be opened at a time.

9.2.3 *Turn and lift*

This was one of the earlier types of child-resistant caps for bottles and tubs. The cap had a ring and lug moulded into the sealing surface and the container had a ring and notch. The position of the lug in the cap and the position of the notch in the container were marked with an arrow moulded into the relevant surfaces. When the two arrows were lined up, the lug could pass through the notch in the container ring and the cap could be removed.

Figure 9.2 Turn and lift pack.

Figure 9.2 shows a typical application of this type of CRC. The arrow on the cap is (in the picture) aligned slightly to the right of the arrow on the container. In this position, the container will not open. Only when the arrow on the container and the cap are aligned (by turning the cap), it will push the cap upwards and off the container.

It is possible to refit the cap without lining up the arrows – thus making the cap child resistant again. One of the problems with this type of cap was that many people found difficulty with opening this cap as the lining up of the arrows caused problems. The moulding of the container and the cap required precision and the lack of any flashing that would aggravate the interference of the lug and slot. This type of child resistance is now outdated because of the difficulty of moulding and use. Moreover, the requirement for child resistance is not only to stop children from opening the pack, but also to allow for use by adults. In this instance, use by the adults is, in many cases, difficult, meaning that the cap was frequently not replaced properly. Besides reducing the shelf life of the contents, this method also negated the child-resistant feature, making child access easy.

9.2.4 Push and turn caps

These caps are generally used for multi-packs of product. When the cap is placed on the container, it needs to be pushed down whilst, at the same time, turning the cap to unscrew. The push and turn operation is difficult for children to perform as they would tend to only either push or turn but not both together.

Figure 9.3 shows a typical application for this type of cap for a pharmaceutical product. Note the gap between the base of the cap and the neck of the container – this is necessary as the cap will need to be pushed downwards to enable it to open. If the gap were not there, the cap would not be able to be pushed down and thus would not open. This is probably the most popular form of child-resistant cap with many different types available in the market from a variety of manufacturers. It is worth noting here that, as with any closure device, adequate opening instructions need to

Figure 9.3 Push and turn pack.

be given to the genuine users to enable them to successfully open the pack. Most of the push and turn caps have the opening instructions either printed or embossed on the top of the cap. In this example, however, there is an additional feature where on each removal of the cap the wording (in the picture 'Wed') rotates to show a different day of the week. This is designed to give an active reminder to the user when the next (or the last) time that the medicine is to be taken. Different combinations can be manufactured to allow for differing regimes of tablet requirements.

Figure 9.4 is showing the sequence of different methods of opening for these caps. Three different pictorial methods are shown, one with written instructions. Two of the caps also show tamper-evident devices as well as the child resistance.

Figure 9.4 Push and turn top view.

Push and turn caps are available in two-part moulding, where the inner moulding has some slots built in and the outer part has some lugs. The action of pushing down on the upper (outer) part allows the lugs to engage in the slots and the cap can be removed. Here it is suitable to mention that the push and turn action is not only difficult for children, but also for those with impaired hand use, such as arthritics. With this in mind, many of this type of closure now incorporate large castellations on the top of the closure to enable a coin or a spoon handle to be used to help unscrew the cap. There are also devices that fit under a work surface to help those with grip difficulties to unscrew these caps.

Figure 9.5 shows a version of a cap that has been designed to help with the opening of this type of closure. The user would insert a square tool into the depression in the cap and use it to depress the inner moulding and turn the cap to open it. With the tool having a large grip area or an offset lever the opening does not require a high degree of force and thus makes it easier for those with limited grip.

Figure 9.5 Push and turn with extension for easy removal.

9.2.5 Squeeze and turn

This type of cap is again available from many different suppliers and relies on lugs on the base of the thread form engaging in the lugs on the container to stop it from being opened.

Figure 9.6 shows a typical application for a squeeze and turn cap. The cap is flexible at the base of the threads and, by pressing the sides of the cap, the lugs

Figure 9.6 Squeeze and turn (top view).

on the cap are deformed away from the container. When the cap is simultaneously turned, the lugs override those on the container. After a turn or so, the lugs on the cap have risen above those on the container and so will not engage further. When the cap is replaced, then due to the contour of the lug profile, they will engage, usually with an audible click.

Figure 9.7 Squeeze and turn.

Figure 9.7 shows a squeeze and turn cap with the indicators of the position to squeeze visible (approximately at the top and bottom of the picture). The two operations of squeeze and turn that must be performed simultaneously are difficult for children (and for those with a weak grip). The method of opening needs to be placed on the cap so that the genuine user can operate the system without any resort to specialised tools. This type of cap can be applied to metal containers as well as plastic or glass. An example of this (although not specifically designed as child resistant) is of a shoe polish container, where pressing the side of the tinplate cap allows the cap to be released from the tinplate container. This particular pace would not be child resistant in its present form, given that it only employs the squeeze without the turn. As with all these types of closure there is usually a reminder to close tightly after use or ‘click to close’. This is because if the closure is not fully closed then the child-resistant property of the cap is lost.

9.2.6 Combination of child resistance and tamper evidence

There are caps available that offer the combination of tamper evidence and child resistance; these dual functions are especially evident on the ‘push and turn’ method of child resistance.

Figure 9.8 Push and turn with tamper evidence.

Figure 9.8 shows a typical range of caps with a combination of tamper evidence and child resistance. Looking from left to right, there is a cap with three white circles in the top face whereas the left-hand cap has a typical drop ring. The right-hand cap when removed, the action of removal is by depressing the outer part of the cap and thus breaking the small lugs that hold the three inner rings in place. This then shows a coloured (red) spot in the centre of the cap. For its tamper evidence the right-hand cap relies on the fact that when the cap is removed, the inserted inner ring becomes detached from the outer cap moulding and drops clear of the cap when the cap is subsequently reapplied.

9.3 Tamper evidence

It should be stated at the outset that this is about tamper evidence and *not* tamper proof. There is no package in the market or that has been patented that is tamper proof. Tamper evidence is about being able to make the consumer aware, as far as possible, that the pack has been opened *at the time of purchase.* It is not very consumer-friendly to incorporate a system of tamper evidence that can only be seen by the consumer after the purchase has taken place. Indeed, not only it is not consumer-friendly, but it is far from the best interests of the brand owner to use such a system, since if the consumer finds that a pack has been breached after they have purchased the product, they are as likely to be as upset with the brand owner as with the tamperer. When consumers wish to open a pack, it is because they wish to use it – this is not the time to find out that it has been tampered with. The tamper evidence must be obvious to the consumer at the time of purchase. If the tamper-evident feature is in any way hidden or difficult to see, then it has failed to do its job.

There have been, in the past, glaring errors in tamper-evident applications. One that springs readily to mind is that of the warning on a carton containing a glass bottle filled with product. The warning on the carton was ‘If this carton is missing do not use the product’. This speaks loudly for itself!

Many systems of tamper evidence exist for different types of product and packaging format. Some of the more common types are given below. It should be noted that the tamperer can, with not too much difficulty and using common items found in the normal home, breach most if not all tamper-evident packaging to give the impression that the pack has not been opened. A sharp knife and a little glue will conceal many of the methods of tamper evidence that are relied upon in the market place today.

This does not mean that we should not use tamper evidence on packs. On the contrary, we should be aware of the ways that the security can be breached, and work to devise new methods to be able to beat the opportunist tamperer. One pack type that has been thought of as being the safest on the market would be the glass bottle and the ROPP cap. Many years ago, in Japan, this was breached successfully with bottles of whisky. The consumers who bought the whisky only realised that the pack had been breached when they found cold tea instead of whisky in the bottle. How was it done? Very easily! Drill a small hole in the base of the bottle, pour out the whisky, fill with cold tea and seal the hole. Who looks at the base of a glass bottle!

This is just one example of a way to beat tamper evidence. I do not intend to give any more examples (even though it may increase the sales of this book but to the wrong readers!) but just to say that other ways of beating tamper evidence do exist. Let us now look at the various methods of tamper evidence that do exist.

9.3.1 ROPP caps

I have already mentioned ROPP (roll on pilfer proof) caps in the preamble to this section and have indicated that they can be breached. Here, the very title is misleading, since, as I have already asserted, there is no such thing as *pilfer proof.*

These caps are metal caps that are placed onto the container; the profile of the thread on the container is used to form the thread on the cap (Fig. 9.9). The base of the cap is also rolled under a retaining lip on the container to affect the tamper-evident band. On unscrewing the cap, the base section of the cap is broken from the main cap section and is retained on the container. It will usually be allowed to drop-down the neck portion of the container so that on replacing the cap an obvious breach is visible. The caps are usually made from aluminium.

9.3.2 Tear band caps

These caps may be manufactured with a range of materials, but are most commonly made from plastics materials (polyethylene or polypropylene are typical materials).

Figure 9.9 ROPP cap.

The tear band is moulded into the cap and, when applied to the container, sits under a retaining rim in the container. This will not allow the cap to be removed until the tear band has been removed. Careful fabrication of the tear band is required, so that it will not fracture when it is applied to the container, and will tear easily when the consumer wishes to use the product.

A disadvantage of this system is that, once opened, the tear band is completely removed from the container. If the consumer is not advised to look for the tear band at the time of purchase, tampering could have occurred without the prior knowledge (at the time of purchase) of the consumer. This demonstrates the importance of advising the consumer of the tamper-evident feature to look for on the pack.

In the example in Fig. 9.10, the tear band is in the centre of the shrink sleeve that has been applied over the top of a screw cap. Here, if the tear band is used, the bottom part remains with the bottle and the top part is removed with the cap. However, in most cases the consumer ignores the tear band (which is sometimes difficult to find) and removes the complete shrink seal by using a knife to cut through the band.

9.3.3 Tear ring

This is a similar feature to the tear band and is incorporated into the cap. The caps are usually moulded in either one or two parts. The single-part mouldings have the tear ring moulded into the cap and, on application to the container, are forced over a retaining ring on the container. On removal, the retaining ring on the container holds the tear ring on the cap and is torn from the main body of the cap. The ring will usually be designed to slip down the neck of the container so that, on reapplication of the cap, a distinct separation of the cap and the ring is evident (Fig. 9.11).

Figure 9.10 Tear band cap.

Figure 9.11 Tear ring closures.

With a two-part moulding (sometimes in addition to a child-resistance feature), the tear ring is moulded into the inner part of the two-part cap; this can be of a different colour from the outer part of the cap, thus making it more prominent to the consumer. The action of application and removal is the same as for the single-moulding cap. An example of this type of closure can be seen in Fig. 9.8.

9.3.4 Tear band

This band is added to the container/cap assembly as a separate operation. The band, either of polyvinyl chloride (PVC), polyethylene terephthalate (PET) or cellulose material, is placed over the join between the container and the cap and, with applied heat (for PVC or PET materials), shrunk onto the container/cap assembly to fit exactly around the contours of the assembly. In the case of cellulose materials, these are added to the assembly in the wet condition and they shrink to fit as they dry out (Fig. 9.12).

Figure 9.12 Shrink capsule with tear band.

Some of the tear bands incorporate a tear strip within them to make it easier for the consumer to remove the band. The band can thus be removed completely from the pack – but, if the consumer is not aware that it should be present in the first place, tampering may be present without the knowledge of the consumer. Some of the bands are printed with the brand or manufacturer's name, or they may be coloured to make them more obvious on the pack; a clear band makes identification of its presence difficult to spot by the consumer.

9.3.5 Tamper-evident labels

Tamper-evident labels are applied in a separate operation after the pack has been closed. Ideally, the label should be applied across the join line of the cap and container. On opening, the label is sheared as the cap is removed. Different types of labels can be used from paper through to plastics and foil. Additional security can be added with the use of printing and holographs. It is far more difficult to realign a printed label than a plain one and, if holographs are used, it is best to ensure that they are placed where the label is likely to be torn. It is essential that the adhesives used for applying the labels be of adequate strength – the shear strength of the adhesive must be greater than the tear strength of the label material. If this is not so then the adhesive bond will fail before the label tears and the effectiveness of the tamper evidence will be jeopardised.

9.3.6 Complete over-wrap

In this process, the complete container and cap is wrapped within an enveloping film of material. The material can be of any flexible material from paper through plastics to metallised materials and foil. The seal on the over-wrap must be such that it cannot be resealed so any of the cold-seal adhesives present a problem here unless they can be manufactured so that the adhesive layer ruptures the over-wrap material. Heat sealing of over-wraps is by far the most common method of sealing (Fig. 9.13).

Figure 9.13 Complete over-wrap.

The opening of the pack must be such that the over-wrap material is ruptured in such a way that it cannot be reapplied. This can be arranged by using a material that has a good ability to tear in one direction (down the pack). Often a small nick is included in an over-wrap to help the consumer to open it and to aid the propagation of the tear so that reapplication is not possible. Printing of the over-wrap also aids the consumer to recognise this as a tamper-evident feature. In addition, one should remember to add some warning on the container about purchase of a product that is not over-wrapped. It is no use putting the warning on the over-wrap! It should be said here that most of the packs that have this type of feature as an over-wrap fail to show the consumer where the teat band is, or fail to leave the end of the band free and available for use.

9.3.7 Carton

Cartons containing product can be made tamper evident in themselves or used to give tamper evidence to another package. The carton will need all its normal openings to be made tamper evident. This will be for both ends (and the manufacturers join) on a skillet carton or all three sides on a top opening carton. The tamper evidence could be as simple as glued flaps or the addition of tamper-evident labels. Since tamper-evident labels have already been discussed (see Section 9.3.5), this section will concentrate on glued cartons.

Although it may seem obvious that a glued carton is tamper evident as there is fibre tear of the carton flaps when it is opened, it is not quite as simple as that. However, one of the criteria for tamper evidence is fibre tear, there are also other considerations. The carton, to be truly tamper evident, will not only need fibre tear for the opening, but the adhesive strength must also be such that the carton flap will need to be distorted in a way that prior entry is evident if an attempt is made to reseal the carton. Thus the fibre tear must be within the layers of the cartonboard and not just a surface tear. In this way the carton is far more difficult to reseal without being spotted. The adhesive bond with the cartonboard must be stronger than the inter-layer bond of the fibres within the board. With this achieved, opening the carton to reach the product will require a two-stage operation. First, the fibres within the board will be ruptured, but leaving the adhesive bond of the inner layer of the board attached to the adhesive. The consumer will then need to break open the adhesive bond and thus enter the carton. This secondary action will give the necessary security to make resealing difficult without detection.

9.3.8 Holograms

Holograms are used as a form of tamper evidence on labels and on foils in such a way that the destruction of the hologram makes tampering obvious. Even the stretching of the holographic image will be sufficient to distort it so that the consumer will be able to detect that something is amiss even though the seal has not apparently been broken. I do not propose to enter the technology of the various holographic processes that are available to the technologist but just to mention that there are several processes that are available with two-dimensional and three-dimensional image recreations.

As with any of the tamper-evident features, the design is important since the utility of the tamper-evident feature is negated if the consumer is unaware of the existence of the device. Consumers must also be aware of what the device is supposed to look like. Holographic images can be successfully used and printed on paper-based or foil-based materials. Care should be exercised if the resultant holographic image is to be added to a pack where it is likely to be stressed in its application, or in the logistics chain prior to its sale in the market.

9.3.9 Diaphragm seals

This section is included in this chapter, although, under the strict definition of tamper evidence, the diaphragm seal is not a true tamper-evident seal. As you will recall, the definition (or requirement) is that it should be evident to the customer *at the time of purchase*. With diaphragm seals, the tamper evidence is only seen when the protective cap is removed, and it therefore falls outside this brief. However, diaphragm seals do form a large area of tamper evidence for dry and wet food products and it would be disgraceful not to include them here – indeed, perhaps this may act as a reminder to packaging technologists that these seals are not seen at the time of purchase, and so may cause customer dissatisfaction if they are seen to have been breached. Diaphragm seals are used on jars or bottles for dry or liquid products and on cartons of liquid products (such as fruit juice). There are three main ways of attaching the seals to the container: (i) *by glue adhesive*, (ii) *by heat seal* and (iii) *by cold-seal application*. With instance

(i) *Glue adhesive*: The adhesive is placed around the lip of the container and the seal is applied prior to the adhesive setting. The diaphragm may be located within the closure on application, thus avoiding the necessity for a separate operation within the packing process. On removal the seal remains in contact with the lip of the container and forms a hermetic seal.

(ii) *Heat sealing*: The seal membrane is placed on the lip of the container (again usually as an addition to the cap) and is sealed into position by heat application. This may be by radio-frequency (RF) welding or by ultrasonic welding. Basically, the two methods excite the surface of the membrane and the seal is heated and adheres to the lip of the container. Each of these methods may require the addition of a lacquer to the membrane or the container to adequately achieve a hermetic seal.

(iii) *Cold-seal application*: The cold-seal adhesive is applied to both the container seal area and the diaphragm material so that when the two components come into contact the seal is made. Pressure is required to achieve an adequate seal but only small pressure may be required if the formulation of the cold seal has sufficient tack.

9.4 Openability

Earlier in this chapter we have considered various ways of keeping products tamper evident and child resistant. We next consider the alternative of making sure that those people for whom the product is intended are capable of using the product as it was intended to be used. In 1998, INCPEN (Industry Council for Packaging and the Environment) issued a code of practice that was endorsed by LACOTS (Local Authorities Coordinating Body on Food and Trading Standards), the Institute of Packaging (now IOM3 The Packaging Society) and many trade bodies, where easy opening was one of the topics covered under 'convenience in use'. This was the first instance where convenience of opening was incorporated into a code of practice for a broad spectrum of users and industries. The code of practice stated that packaging should be convenient, easy to open and consistent with providing satisfactory containment and protection of the contents. Regard must be shown to users who have disabilities.

Several points about consumers need to be considered in order to address the openability issue clearly. Who is the intended consumer? Many products are intended for use by consumers across a broad range of ages and mental and physical abilities. All of these need to be considered if the intended consumer is to be able to open and use the product as it is intended. The last thing we would want is for the pack or the product to end up as yet another statistic of the accidents in hospitals. It has been said that there is no such thing as bad publicity, but anyone who is involved in handling complaints from angry consumers about bad packaging would not agree with this. Bad packaging leads to loss of product sales. Indeed, when consumers were asked to rank five different attributes of packaging, ease of opening was well ahead on the list as a requirement.

List of packaging attributes

Ease of opening	93%
Legibility of typography	78%
Handling ability	60%
Recyclability	50%
Graphic design	28%

Therefore, ease of opening is an important consideration while designing packaging closures. Moreover, we must not forget that the consumer trend is changing and that the average age of the consumers is advancing. Advancing age brings with it other conditions that affect the way we understand or interpret or act upon any instructions given on a pack. In the United Kingdom alone, there are some 6.5 million disabled consumers. Of these, one million will have difficulty opening a jam jar (not only the first time, but every time). With the market extended to Europe and the 150 million 'third age' consumers, the scale of this concern becomes clear. This picture is not confined to the United Kingdom, but can be mirrored in many countries throughout the world.

In Britain alone, there are 1.7 million people with impaired vision who are registered as blind or partially sighted. This does not include those who wear glasses, or are illiterate, or who do not speak English, or are dyslexic, or are arthritics or have other physical ailments. We may decide that the pack we are designing is not for the 'third age' consumer but again we need to consider the 2% of below 16-year olds that are visually handicapped, or the 2% of the visually handicapped that can read Braille. We need to remember that 55% of people with visual handicap live alone. Additionally, with the migration of populations and the ease of international travel field, the experience in the United Kingdom can be extrapolated to many other countries to the same or similar degrees.

If a pack is difficult to open, a consumer will revert to other methods to open it, rather than that preferred by the packaging designer. This means that we have failed to give the consumer the expectation that they had when they bought the pack. This failed expectation reflects on the product and on future sales. Furthermore, if the consumer finds difficulty in opening the pack, they are already in a bad frame of mind when it comes to using the product. Another disappointment may be when next in the store to purchase more product – this time they will try another brand.

9.4.1 Can openability

For can openability, the obvious issue is for the ring pull can rather than cans that may be opened using a tin opener. The ring pull technology is discussed in detail in Chapter 3 (closures for metal containers).The ring pull has many advantages over the tin opener for opening cans, but there are also some drawbacks as well. 'Third age' consumers do find that a ring pull gives problems with grip – the rings tend to be too small to grip and with the ring lying flat on the top of the can it is difficult to prise it up to pull it. Again, because of the technology of the ring pull, the force required to puncture and pull is too much for many consumers. Back to the knife drawer to find something to open the pack! However, the ring pull end is an advantage over the older version of the use of a can opener (that could leave a sharp edge on the can to cause cuts to the user) or the 'key' system used mainly on small fish tins where a tab on the can lid was inserted into a slot in the key and the key was wound round opening the lid of the can. This lead to many failures and injuries to the users.

9.4.2 Flexible packs

Although many flexible packs are secured with heat seals, there are problems when it comes to openability. There are many comedy sketches depicting opening of the breakfast cereal pack and the contents spilling all over. This may cause some amusement to the consumer but it is a real problem. Several manufacturers of flexible packs have tried to address the problem with the use of a tear tape. Some add a notch to the pack to assist in the propagation of a tear. Others use a cold-seal adhesive instead of the heat seal. All are valid methods of assisting the consumer to open the pack effectively. The problems are not only with the choice of opening but also what is going to happen with the product as it is used. Is the pack a single-serving or a multi-serving pack? Does the consumer need to re-close the pack? Is the closure system effective? Each of these questions needs to be answered alongwith the obvious question of whether the consumer knows how to open and close the pack effectively. It is ensured that the sealing mechanism is effective but little thought is given to the method of use or the instructions to the consumer.

9.4.3 Tear tapes

The incorporation of a tear tape to the packs allows the consumer to open the pack with little effort. However, if the existence of the tear tape is not obvious or indicated with words or pictograms, the consumer will not be aware of its existence. How often have you seen a tear tape, which you know is there but you cannot find the end from where to operate the tape? I'm sure that your answer is the same as most people – many times!

Tear tapes are only effective if their presence is known and the end of the tape is easily available even to those of limited dexterity. The other important aspect of the tear tape is that the tape must be able to propagate an effective tear in the wrapper. Most materials used for flexible packs are able to tear better in one direction than the other. This then necessitates the tear tape to be applied to tear in the weakest direction of the wrapping material. If the tape is placed, so that the strongest direction on the material is in line with the tape, then it becomes ineffective in operation. So tear tapes need to be placed: (i) in the weak direction of the material; (ii) with the end extending from the wrap; (iii) where it is visible to the consumer; (iv) in a colour that is easily seen and (v) where they will completely open the pack. Adequate instructions for opening also need to be included.

9.4.4 Cold seal

As distinct from heat seals, a cold seal is applied to a flexible pack without the use of heat in the sealing process. Usually the cold-seal material is pattern applied to the inner surface of the wrap material. The cold-seal material is usually a latex material, which will be applied to both the surfaces and will eventually form the seal. When the wrap is formed, the two surfaces that have the cold-seal material applied are pressed together to form a seal. It is possible, especially in some applications where the temperatures are low, for slight heat to be applied at the time of sealing.

Cold-seal materials are not effective if the conditions at the time of sealing are of high humidity, or the surfaces are wet or greasy.

The advantage of cold seal over heat seal is that the machine speeds can be higher and that delicate products can be flow wrapped without the addition of heat to the product. However, there are disadvantages in cases where the cold seal needs to be applied to the packing material only at the seal areas (for food products) to avoid contact with the product. As latex materials give off ammonia, contact with food products is to be avoided. Many of the materials do not conform to the requirements of the Materials and Articles Act in contact with food regulations, hence care must be exercised. However, cold-seal materials do have the ability, if correctly formulated, to allow for satisfactory resealing of the pack after some of the contents have been removed. So cold seal can have a reseal property and thus care needs to be exercised if tamper evidence is a problem. The possible advantage of cold seal is that the seal strength can be adjusted to allow for a satisfactory seal and also allow for a satisfactory opening of the pack by the consumer.

9.4.5 Diaphragm seals

This type of seal is common on many bottles and for carton board containers for liquids and tins where the manufacturer wishes to have a good shelf life of the product, and also offer some degree of guarantee to the consumer that the product is 'factory fresh' and has not been opened. The seals are either adhered to the container mouth or are formed into the seam of a can. Many consumers find difficulty in opening diaphragm seals, as the two conflicting considerations often are contraindicated. These two contraindications are (i) an adequate seal that will contain the product and give a hermetic seal and (ii) a seal that can be easily opened by the consumer without the use of a tool.

The first requirement of a good hermetic seal is to ensure that the seal will remain intact throughout the storage and distribution chain; a strong bond between the container and the diaphragm is essential. Any rupture of the seal bond will allow product seepage and spoilage from microorganisms.

The criterion for the consumer is that the seal may be easily removed when the product is required. To this end, the use of a tear tab should be considered where the consumer could pull the tab and with relative ease break the bond between the container and the diaphragm. Tear tabs should be large enough to allow for the consumer to be able to peel back the tab whilst having a good area to grip. Many people with grip and dexterity problems will need a larger tab than those with more nimble fingers. The size of the tab may become crucial when designing the feature, as oversized tabs will increase the cost of the pack and undersized tabs will be ineffective. It is a feature that needs to be tested, not only with the technologists and marketers, but also with the users who may have dexterity problems. Without the use of a tab or some other opening device, the consumer is left with no other option than to use a knife and risk cutting themselves in the process.

9.4.6 Vacuum formings

This area is probably one of the most frustrating for many consumers, be they able bodied, dextrous and/or have a high IQ. How many times has the single serving portion pack failed to open properly or failed to inform how to open it? The single serving of milk where you end up with more milk on yourself than in the coffee. Or the single serving of jam where you recourse to opening it with the knife because the corner is not cut properly or you cannot find the portion of the lidding foil that is not adhered to the base forming? The list is endless. Perhaps if the pack opening was standard for these types of packs then the problem would, in time, disappear. This is unlikely as the changes to different machines within factories and the collaboration of machine manufacturers would be required. Each manufacturer would want to have a 'better design' than their competitors. However, these are not the only products that aggravate the users. Many of the blister packs that are manufactured with a vacuum forming and a backing card are difficult to open. Some do have perforations in the backing card to assist in opening the pack, but some do not. A little forethought with the pack design would allow the consumer to open the pack more easily. It is important to remember that even if some consumers have dexterity problems, they do not have memory problems and they remember this when they decide to buy another brand. If they had difficulty opening the pack, they are likely to avoid making another mistake when buying the next time. Your competitor will gain from your lack of forethought in your design.

Vacuum formings are used very effectively for different products in the shorter shelf life range of products and are very efficient in achieving their intended design criteria. Fresh products, where the main purpose of the pack is to contain the product rather than to extend the shelf life, is well suited to vacuum formed packs.

Figure 9.14 shows a typical vacuum formed pack for sandwiches where the lid is an integral part of the container. To affect a closure, the lugs on the lid fit within the depressions on the body of the container (Fig. 9.15).

These lugs and depressions are a snap fit and a secondary sealing may be made with the use of a label seal. This helps to form a tamper-evident seal on the pack. Other containers and closures are used for different products. For example, with fresh fruit the requirement for the container is to hold together a number, or weight, of fruit. There is no need for a hermetic seal. The fruit must be allowed to breath and any moisture allowed to escape rather than remain inside the pack. Moisture would allow mould growth and shorten the shelf life of the product.

There are instances where the lid and container are separate mouldings. Here the closure is affected by the outer rim of the container and the inner side of the closure coming together to be snap closed. With this type of closure a hermetic seal is not usually required and so the rather loose pack (a thin vacuum forming) is acceptable (Fig. 9.16). In some instances, such as for fresh fruit, the deliberate introduction of ventilation holes in the lid helps to keep the product in its best condition for as long as possible.

Figure 9.14 A typical vacuum formed pack for sandwiches.

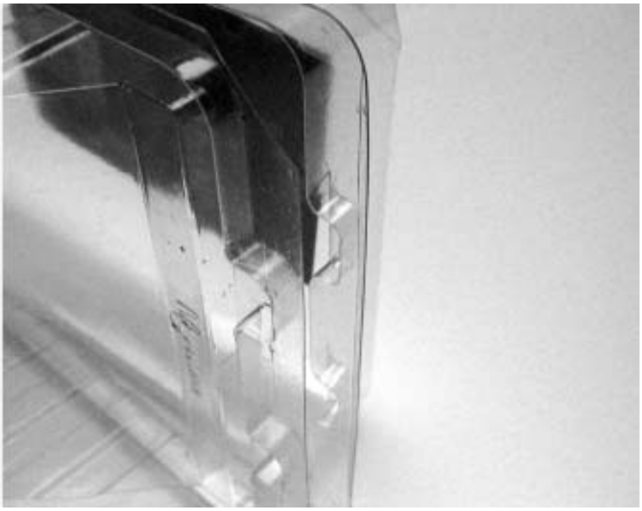


Figure 9.15 Typical closure lugs.

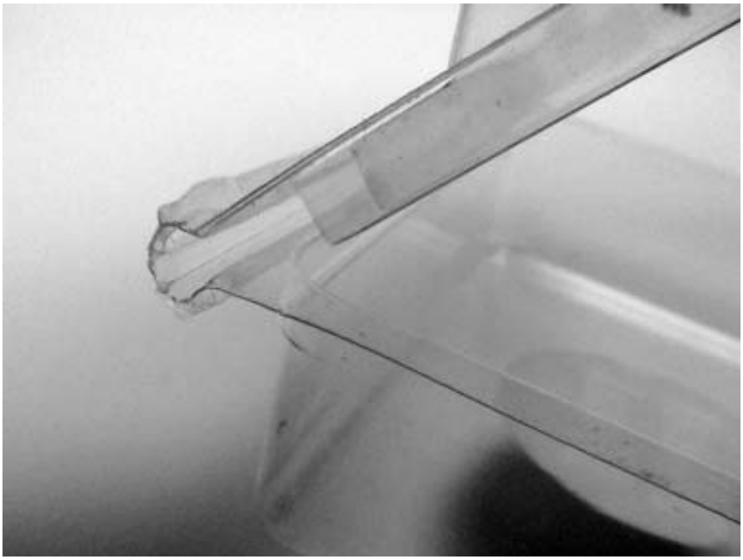


Figure 9.16 Typical vacuum forming showing hinge detail.

9.4.7 Bottles and jars

As with many of the packaging problems that are encountered, there are conflicts between requirements. If life were easy, would we need packaging technologists! For screw-threaded bottles, the conflicts are in the closing torque and the opening torque. The closing torque needs to be sufficient to seal the bottle under all the conditions of storage and transport that are likely to be encountered. Export travel through different temperature and pressure areas could well require a different closing torque due to the differential expansion and contraction of the container and closure materials resulting in 'backing off' of the closure, where thread profiles are not matched. However, excessive closing torque could lead to failure of the closure due to the stress set up in the closure material being greater over time than the inherent strength of the material. The so-called 'environment stress cracking' that could result from reactions of components of the product and the built-in stress within the closure are all problem areas. However, opening torques are areas of consideration for the technologist. Most torque measurements are carried out on a torque meter, where either the container or the closure is gripped firmly in the machine whilst the other component is unscrewed. This test does not replicate the actual 'in use' situation where the consumer will be holding the container and unscrewing the closure. The size of the closure and the configuration of any ribs, etc., will make a difference to the ease of opening and therefore the acceptable opening torque. The smaller the closure, the lower the opening torque that is required for suitable operation. This is a general rule of thumb but other factors do influence the outcome.

Other influences on openability in this area are with containers that are post-filling pasteurised or sterilised and have a residual vacuum within the container after processing. The retained vacuum results in a difficult-to-remove closure. Many people, including those with dexterity in their fingers, find these closures difficult to use without resorting to some form of tool. The most common examples of this type of container are those used for jams and wet baby foods; for these, the user may resort to prising off the lid with a knife or stabbing the lid with a fork to release the vacuum. Both methods are far from desirable. One manufacturer of lids has designed a lid with a thinner section that is 'designed' to be punctured with a fork to help with this problem. However, this still requires a tool to open the pack. Perhaps thought should be put into designing a lid that does not require a tool to open it and thus avoid the risk of injury to the user.

9.4.8 Cartons

These are one of the least problematical of the container systems. However, the need for tamper evidence and thus secure closure will of necessity demand a good review of how the carton is to be opened. The use of tear bands within the carton construction aids secure sealing and easy opening. Care must be exercised, however, in ensuring that there is also an adequate closure device if the carton is to be used as a multi-dispensing alternative.

9.5 Conclusion

In this chapter, I have given examples of the various ways that child resistance, tamper evidence and openability may be considered. The technology in the packaging field is advancing rapidly and new ideas are flowing in the market almost daily. Packaging technology is one area where the designer needs to be fully aware of all the possibilities and drawbacks of each of the component technologies. The packaging technologist does not only need to know about packaging, but must also be aware of the basics of the product that is being packed, the distribution systems that are used, the market conditions and the marketing advantages of the various types of pack that are available to them. A jack of all trades and yet still master of many! The problems that are highlighted in this chapter (regarding the three opposing, but related, subjects) emphasise the importance of considering one aspect of the total package whilst concentrating on another.

All these aspects of the total package are important if the package (that sells the product initially) is to work satisfactorily to allow the user the satisfaction of a repeat purchase (subject to product satisfaction). The package sells the product initially as well as acting as a recognition tool for a repeat purchase. With any package design, it is important to build up customer satisfaction and assurance. Assurance that the product *is* in the same condition as it was when it left the factory (with proper tamper evidence) and that the product (with the pack) is safe whilst in the home. Satisfaction that the product has reached the user, through its journey, in a satisfactory condition and that it can *safely* be used. It is important not to underestimate the value of the packaging in giving the customer the confidence with the product.

Some aspects of the pack have not been discussed here (print legibility, legal requirements for listings, trade descriptions, waste recovery and many other packaging related issues). This chapter is purely about child resistance, tamper evidence and openability. The packaging technologist needs to consider all aspects of the complete package and its potential for selling on the shelf if the product is to be successful. Let the imagination run riot to start with, but be aware of the possibilities that are available, and could be available, with a little imagination by the technologist and the supplier companies. If the product you want is not available then you should ask why – just because it is not available now does not mean that it cannot be available if you push for it.

It should always be remembered that, where a feature is included in a pack, it is there for a particular purpose. If you consider tamper evidence, this should alert the consumer to any tampering *at the point of purchase.* There is little use in adding tamper evidence if it is only seen when the product has been purchased and potentially consumed!

Figure 9.17 Tamper-evident labels.

Both the jars shown in Fig. 9.17 have tamper-evident labels and both have their labels showing in the front. However, the jar on the left has a very evident paper label, whereas the jar on the right has a transparent PET label. It does not require much imagination to see which jar the consumer will be able to see and check before purchase.

In Fig. 9.18, both bottles have ROPP caps with tamper-evident features. These can be clearly seen in the figure. However, one bottle has been opened and the other

Figure 9.18 Tamper-evident ROPP caps.

has not (Fig. 9.19). Thus, it was possible for the product in the opened bottle to be substituted for a different product and the consumer would be none the wiser until they consume the product. Too late!

Figure 9.19 Opened and unopened TE ROPP bottles.

It is easy to see in Fig. 9.19 which bottle has been opened but if a different product was refilled into the bottle on the right – who would know?

Tamper evidence must, if it is to be effective, be *evident.* In both of the examples in the figure, the tamper evidence was not evident and thus not only did it not serve its purpose but it added cost to the production of the product and it could have been fatal to the consumer. Adding a degree of confidence of tamper evidence to the pack gives the consumer assurance that the pack has not been tampered with. If the tamper-evident feature is not effective, then that confidence can be fatal for the consumer! *A tamper-evident feature that fails to work is worse than not putting the feature there in the first place.*

The estimated value of packaging throughout the world is $424 billion for 2004, with a growth rate of about 22% up to 2010 ($521 billion). Europe uses about 30%,the United States 28% and Asia 27%. The vast majority of this market is in containers, with a decreasing use of secondary packaging (as the effects of legislation on packaging minimisation takes effect). Food packaging is expected to grow by about 4.6% p.a. and pharmaceuticals by 4%. With this expected increase in the quantity of packaging, it is evident that safety of packaging and packaging/product interactions will become of significant interest to both the authorities and to the consumer. All packages will need to have some thought about the aspects of child safety and tamper evidence. About half of the increase in packs will be metal closures, which are the most common for causing accidents in the home. Plastic closures are catching up in numbers, and cause fewer accidents. It appears that the industry is looking at the effects of openability for product packaging and it is hoped that the incidences of hospital visits will diminish as a result.

New regulations will appear on child safety and new products will be brought within the requirements as new dangers to health are seen. Areas where new regulations are seen to be developing are in cosmetics (cosmetic stick products are under review in the United States). Moreover, the tampering of products will not disappear and is, in fact, likely to increase over the years; thus, the design of packs must have this aspect of product protection and the market requirements in sight at an early stage for all products, both new and existing. The average age of consumers is rising and so openability is a sensitive issue. The third age consumer is more discerning and less tolerant of shortcomings in package design. The success or failure of your product may well depend on your ability to address these issues successfully.

Child resistance, tamper evidence and openability are three important aspects of the total container/closure system and, as such, deserve a high degree of consideration by the technologist and in the marketing scenario. They are both an assurance to the consumer and a safety issue: child resistance to stop children being poisoned; tamper evidence to give the consumer confidence that the pack is in pristine condition; openability to give the consumer ease of access to the contents without having to resort to dangerous methods of opening the pack.

9.6 Regulations

BS EN28317: 1993 Child-resistant packaging. Requirements and testing procedures for reclosable packages

ISO 8317: 1989. (As BS EN28317: 1993)
BS EN 862: 2001 Packaging Child-resistant packaging. Requirements and testing procedures for non-reclosable packages for non-pharmaceutical products
BS 8404: 2001 Packaging Child-resistant packaging. Requirements and testing procedures for non-reclosable packages for pharmaceutical products
BS EN 14375: 2003 Child-resistant non-reclosable packaging for pharmaceutical products. Requirements and testing
BS EN ISO 8317: 2004 Child-resistant Packaging. Requirements and testing procedures for reclosable packages
Poison Prevention Packaging Act 16 CFR Part 1700 (most notable in the United States)

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